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THE FUTURE OF AGRICULTURAL SCIENCE[1]

SIR A. DANIEL HALL[2]

Mr. President and gentlemen:

I owe you an apology for attempting in an informal talk to assume the position of a reviewer of the way agricultural science is being pursued at the present time. I would like to begin by asking you to bear in mind the enormous increase in the specialization of science. I recall, for example, that it is almost exactly fifty years since I was taking my final examinations at Oxford in chemistry. And at that time students who were taking the Honour School of chemistry at Oxford were expected to be acquainted with the whole of that science, and to have read it right up to current research. We were expected to be able to answer questions about investigations that had been published say within a year of taking our examination. That was only fifty years ago. There was indeed a differentiation between organic and inorganic chemistry; but the more modern differentiations of physical chemistry, bio-chemistry, colloid chemistry, electro-chemistry, etc, were entirely unthought of. Then, as I say, one man was supposed to be able to cover the whole subject. At the present time, of course, no man pretends to know the whole of physical chemistry, still less the whole of chemistry, even if he is spending his life at it and is not merely an undergraduate undergoing his final examination.

I think the same thing holds true very much with regard to the progress and the methods of agricultural research. Looking back I realise that the formal organization of agricultural research in England has taken place during my life time, although research existed, of course, long before my time. The Experimental Station at Rothamsted began nearly a century ago but it was then a private institution, receiving no assistance from the State. It did in fact represent with one or two minor exceptions, the whole of the agricultural research that was then going on in Great Britain.

Somewhere in the late eighties and more particularly in the nineties organized agricultural research got a start in Great Britain, and when I look back upon my colleagues of that time who were recruited from the various fields of science to begin the new work, I see a very different type of man from the current research worker, for in those days a man was supposed to be able to cover the whole field of agriculture and the sciences depending upon it. I can best give you an example by recalling to you the late Professor T. B. Wood, whom many of you knew. For many years he was Director of, and indeed the creator of, that great school of agricultural science at Cambridge. Now T. B. Wood was indeed the all-round man of science in connection with agriculture. He was a farmer in the first instance, born and bred upon the farm. He went on farming himself; during the whole of his Cambridge

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[2]Director, John Innis Horticultural Institute, London, England.

career he was running a farm of his own, farming, as he was always proud to say, out of his own cheque book and not with the resources of some institution behind him, and therefore having to make it pay—and indeed he did make it pay. Besides that he was the head of the Institute of Research in Animal Nutrition at Cambridge. And he *was* the head of it, that is to say he was the originator of the methods of work, and he was controlling and directing research in that particular field. He, of course, was head of the School of Agriculture and as such was responsible for the general oversight of the institutions that dealt with animal diseases and plant breeding at Cambridge. He had papers to his credit on such divers subjects as the composition of mangolds, the colloids of wheat flour, Mendelian inheritance in sheep, and probable error in experimental plots. Well now, we are not likely again to see men of that type, who have this immense all-round acquaintance with all the development of science in connection with agriculture. They were men like the Greek, Milo of Crete, who by practicing with a calf gradually grew up to be able to carry a bull. Now-a-days the investigator is confronted with a full grown bull, and can not begin to learn to carry it.

Specialization, then, is a fact to be faced. We recognize the enormous power of the specialist, his way of penetrating into the mysteries; and in agriculture we are concerned with that most mysterious of all things, life. Yet we have to guard against some of the dangers to which our research is exposed. The danger arises, perhaps, from the interest of the subject itself. If you get a man working intimately, closely, with some problem of soil or of disease, he becomes so fascinated in the pursuit of knowledge that the end to which his researches are directed becomes forgotten in the interests of the problem itself. The means, as it were, become far more important than the end. This is almost inevitably so; and, of course, some of these problems as in soil physics or some of the elusive problems of mycology or of genetics lead on and on with no prospect of finality, so that the investigator settles down, as it were, for life. He will have colleagues in other countries similarly carried away by this intense specialization until in the end a sort of bridge party is made up. A worker in the United States "leads"; somebody in Jugo-Slavia plays the next card; there is a third person in England, perhaps, who joins in; and then you have a fourth from Holland or Sweden to play. These people all exchange papers with one another. They all feel very important and are entirely interested, but wholly indifferent to those outside the party. I had an instance in my laboratory not long ago, when one of my colleagues had prepared a paper. I toiled over this paper trying to get it as I thought intelligible—at any rate intelligible to myself—day after day; and about the tenth day, after talking it over I said, "Look here, you must begin again and write this all over; it is not really intelligible." And the lady—it was a lady in this case—turned to me and said, "What does it matter, there are only five people in the world who will read it and they will understand it." Well, that is the sort of game that our science may so easily become.

This high specialization exists; it is inevitable; and we can't get the best work done, and we can't solve or even get an appreciation of many of the difficult problems that are before us unless we have such specialists each at liberty to go on working in his own way, and pursuing his particular bent to the utmost. But can we do something to make these people human? In order to do that let us try to ensure that they have contacts with agriculture

itself. In my own particular field at the present time I am concerned with genetics and plant breeding. But one has to try to make the young workers taking up genetics become interested in plants and in the actual growing of plants. They must not treat the plants that are being grown, perhaps by the thousands for their particular genetical study, as merely laboratory units but as living things, possessing other points of interest than crossings over in certain proportions or chromosomes in certain positions. What we have to try to ensure is that all our workers are making contacts with the practical man. We do this first of all to ensure that their work will have some immediate practical purpose; of course we must ever remember that the purest scientific work may suddenly bloom into something utilitarian. Just think, for example, of the number of men and of the length of time that was spent in the minute study of the nuclei of plants and animals, work which eventually defined the chromosomes and revealed the processes of mitosis and meiosis. For years and years that was abstract, pure science without the slightest thought that it was ever going to be of any practical value. Suddenly it blossomed, and in the hands of Morgan and his colleagues this study of the nucleus provided a physical basis for the Mendelian generalizations. So we obtained the whole material basis of the regulated breeding of plants and animals out of that bit of abstract, pure science. None the less I think we are more likely to get even our pure science work vital if we can persuade the workers to be agriculturists, horticulturists, and above all naturalists who have their eyes upon the living, growing organisms. It is peculiarly important in another way. Often it is only when you turn to the practical man who is working upon a very large scale with plants or animals that factors are disclosed, exceptions are thrown up, and difficulties are discovered which do provide a lead perhaps into the ocean of pure science itself; and, therefore, it is good from both the pure science point of view and the immediate needs of the practical man that all our research workers should have, as it were, their ears to the ground.

How can that be done? Well, as a working method, can we not allot to each of our workers in the laboratory together with his real fundamental problem that may require years of investigation, patience and the colaboration of many people, some proximate, short-term problem that arises from farm or garden itself? The one will give him his contacts and may suggest further long term problems; the other is, of course, his permanent fixed occupation. I think it is a reasonable way of going to work, to see that the abstract research worker has also a practical investigation which may bring some immediate help to the farmer or the gardener.

Now, may I pass on to consider briefly indeed what are the directions in which scientific research in regard to agriculture may probably be guided most profitably at the present time. I embark upon that question with a little more confidence in that we have recently set up in Great Britain an Agricultural Research Council, the opposite member to the Committees dealing with Scientific and Industrial Research, and with Medical Research in our country. It has been the duty of this Council to carry out a general review of the agricultural research that is in progress in Great Britain, and in so doing it has had almost necessarily to think a little about what is going on in the Empire and in other countries. While the review is by no means complete I think we begin to get the various subjects into a little perspective,

and to see something of their relative importance. Perhaps the subject that has most been pressed upon us, the one which to most people seems to require the most strenuous effort, is the question of animal disease, or rather, as I should put it, the question of ensuring animal health. Many people do consider that the most pressing of all the problems before us.

Now I am bound to say, while reporting this as the general opinion, that I do not personally altogether agree, because I am looking at the problem from the point of view of health rather than of disease. I see the task of the people who are dealing with the health side of animals to be in future very much more hygiene and the maintenance of health than the cure of disease. What I would like to see is a class of veterinarians who are officers of animal health rather than practitioners. There must always be practitioners who are concerned with surgical cases and with specific illnesses of valuable animals, but it seems to me that the great efforts of the profession should be rather of a public nature. Instead of being called in to this ailing cow, or that fretting horse, we want to see a class of men who have charge of a district, who are thinking about the horses, the cattle, the sheep and the pigs and how to keep disease away from them. Naturally, they will have to know about the endemic diseases, but breeding, environment, nutrition, and other factors in hygiene will be equally important. I think that is going to be the direction in which the veterinary profession itself will eventually move, and that the veterinarian of the future will be the kind of public officer who is taking prophylactic and preventive measures and who is studying problems like nutrition and so forth, so as to ensure a greater amount of health amongst the animal population. You see it is only latterly that we have really begun to appreciate what an enormous factor nutrition is in the health of livestock; we don't even yet know all that is necessary.

From another point of view I think we shall really have to attack these problems of animal disease and their occurrence from the genetic standpoint. We know of course already, in dealing with plants, how a great number of diseases can effectively be dealt with by breeding immune races. We have succeeded in breeding races of potatoes which are immune from corky scab, or the wart disease as we call it at home, a disease which a few years ago threatened to wipe out potato growing in many districts of Great Britain. In all kinds of directions we can see how the most profitable and certain attack upon diseases in plants is to breed a race that is immune. We can't dispense with measures of spraying at the present time because it takes time to breed immune varieties, first to find immunity, and then to breed from it. And when you are dealing with fruit—well a generation of apples in our country means seven years, and so the research worker isn't going to get very many generations in his own lifetime. But still this line of attack has been so profitably pursued in many directions that one can be reasonably sure that in the end our real method of dealing with disease in plants is going to be from the genetic side. I think the same method will come amongst animals. There are cases—you can quote instances—which show you that certain kinds of immunity are inherited through characters subject to the laws of inheritance that have been worked out for other characters. If then we are given time and space and numbers, I think we can do much to create races which will be immune to many of the diseases that cause such large monetary losses at the present time.

That leads me on to consider another very big problem before us. Many of our economic problems in dealing with animals, besides this one of disease, can be solved if we can only set to work at the breeding of animals with the same intensity and on a scale comparable with the methods that we have employed with plants. It is going to be a difficult matter because of the complications due to sex, difficult also because so many of the characters of animals are governed by environmental conditions as well as by genetic make-up. We shall have to deal with large numbers of animals and that means expense. Such work again becomes difficult because we have to fight to a certain extent against the inherited traditions of the farming community. I say we have to fight against the inherited traditions because we do come up against the devotion of the best farmers to their conception of pedigree. If you are going to set to work and breed say a new type of sheep that shall combine a great many advantages that are scattered about amongst the different breeds of sheep at the present time, you at once are opposed both by the vested interests in existing breeds and by that instinctive, persistent, long-inherited tradition of the farmer that pedigree is a thing to look to for its own sake. Pedigree was a great step in its day, and the principles that were laid down by the earliest breeders of animals have done marvellous things in improving livestock. But, as you all know, pedigree that is founded simply upon records of breeding and upon show performance is not really sufficient. I have been interested to notice how much progress you are making in Canada in working out performance records and new types of pedigree for many classes of livestock that will, for instance in regard to milch cows, show records of performance in the past; records of the performance not only of the dam, but records of performance of the bull showing his ability to get better milk-producing stock. We are tentatively beginning to recognize performance records of that kind with regard to the breeding of pigs. We don't simply want to know that the boar is of such a line and won such and such a prize at various shows; we want to know the record of the litters he got, and how steadily he carried with him a commercial degree of prolificacy. And for all the animals that we have to deal with we need this new conception of pedigree, which shall be based upon performance and which shall be an assurance of performance in the future.

But I want to go further than that and to begin recreating. I do deliberately say that the time has come when our knowledge of the laws of inheritance that have been worked out in connection with the smaller animals at the present time has become sufficient to enable us to step forward and create new breeds. I call them synthetic breeds, because I want to put together within our new breeds many of the excellent characteristics that are at the present time confined, perhaps, to one or two breeds only. It certainly can be done. The only question is whether any of us will have the courage to set to work upon a scale, and to face up to the financial expense, that such breeding will involve during the early stages.

One can begin to see that not only the time is ripe for such work from the scientific point of view in that we are beginning to have sufficient knowledge of how to breed for milk or wool, but perhaps we are getting to the stage when we can see from the economic point of view how it can be done. After all are we not in Great Britain just beginning to feel out towards—I won't say simply co-operation in agriculture—but towards a planned agriculture. A planned agriculture will involve a certain amount of direction and control

of methods—I won't say of the actual work—of the farm. At the present time when contributions for research are being cut down it would not be much good asking for a farm of adequate size, and say 20,000 head of cattle to begin a new breed. But if there is central market control it ought not to be so difficult to ensure the co-operation of we will say 200 farmers, each with a certain number of cattle, towards such a common objective, that the cattle are all to be bred under direction, generation after generation towards a new synthesis, a new type of breed. It is quite true that at first you would be producing a set of mongrels, but then the loss to each individual through the mongrels would never be great and would disappear as the new breed emerged. I believe that some such organization will make it possible to ensure a genetic improvement in our existing breeds of livestock.

I am bound to tell you that when I have thrown this idea out in public in Great Britain it has been received in the coldest fashion by any farmer who happens to hear it.

Well now, on this occasion, talking in an informal way, you won't want to hear me say anything about the problems of genetics in plants, particularly the problems of disease and that most insidious class of diseases lumped together as virus diseases. Sometime there will be another occasion on which I may be able to deal with these questions. Nor again do I think this the occasion to discuss many of the new lines of thought that have been pointed out for us in considering problems of the soil.

If there is one other line of research which one really would like to say something about, it is the field that is opening up with regard to the minute physiology of plants. One of the difficulties in dealing with plant physiology in the past has been the purely technical one of analysis. New methods of micro-analysis are being worked out to an extraordinary degree, and appliances are being put at the disposal of the research worker engaged with the intimate physiology of plants that are altogether outside our conception of even twenty years ago. It was only the other day when I was in Pasadena that I was shown the methods by which micro-analysis of the chromosomes is being attacked at the present time. It is now possible to identify certain mineral elements in particular chromosomes of a plant. Well, that is pushing refined analysis to an extreme; and, as I say, in the light of these methods and some of the results that have already accrued, I believe this is going to be one of the most fertile lines of attack that remains open before us. It is an extraordinarily difficult method to follow, but one which will have a bearing upon our practical problems of plant growth in many and diverse directions.

But however much we look over the field of agricultural science and research work in connection with it, we are sooner or later up against the big economic problem. What is the good of all our science, and what is the good of all our research, if the fundamental basis of agriculture as a means of enabling men to live by tilling the soil and raising animals is wrong; if the farmer can't get a living, and if the improvements that we can promise from our science weigh so little that they can not overcome these fundamental economic problems? This point of view is something that those of us who are dealing with research in agriculture can not afford to put out of our minds; that behind all our efforts, behind all the improvements that we may suggest, behind the transformations that we can make in our farming, we

have to consider the ultimate transformation of the farming individual. Yours is almost single-man farming, ours a little more organized into small capitalist units; how are such men to be fitted into the organization that modern thought, modern science, modern improvements seem to demand? The demand is insistent—the human mind once having got upon this efficiency track will go on pursuing it. The agricultural problem is how to ensure this type of efficiency while at the same time not effecting utter social disorganization by entirely knocking out the individual peasant farmer. At present the competition between the peasant and the great organization is still perhaps a little doubtful. I don't think the case for the big organized scientific farm has yet been proved up to the hilt.

It was only the other day I was being taken over one of these big organized ranches in Southern California, something like 6500 acres chiefly under fruit crops of one kind or another, all managed with the sort of efficiency and organization that we normally associate with the factory. The control of labour and materials, the organization of transport and marketing, all seemed to me just about as good as you possibly could get as far as I could see from a casual inspection, and some examination of the books and records. And yet, with all that, the people who are running the show confessed to me that they didn't know whether they were really going to succeed or not, as compared with the little individual man who had his four or five acres of oranges or of apricots, and did all the work himself.

The utmost advantages, as I say, of organization and science, and wealth and capital and so on—big business *in excelso*—were still fighting a not certainly victorious battle against the family farmer who is willing to put in his twelve or sixteen hours a day on his own little potato patch. Well, I can't but think in the end that the big man with this form of organization is going to win out. Up to the present time the individual has kept his end up by working twelve hours a day, and by indenting upon the time of his wife and his children. In many countries he shows that he is getting rather tired of the job and prefers to earn wages at the factory that has sprung up nearby; or at any rate if he sticks it out his children are not disposed to carry on in quite the same way. We can see in the Old World the disintegration of the peasant system under the attractions of industry and the pressure on prices started by the big organized farm, which in many quarters has progressed far enough to have made the living of the peasant very precarious.

Well, as I say, that is the ultimate problem that is before us. We are all aiming at efficiency, the more efficient production of plant food from the soil, and the more efficient conversion of that same plant food into animal food. Every time we have one of these revivals in efficiency—and revivals have been effected within our time—there is a renewed attack upon what is after all the mainstay of farming all over the world, the individual, single-man, peasant cultivator. I think it is up to us to have that problem always before us, and see that economic investigations go hand in hand with our scientific investigations. The one great objective in these economic investigations ought to be to see how far it is possible to organize these individuals who are at present weak, scattered units, to organize them so they can take their part in one of these big efficient organizations and yet remain still independent human beings, inheriting the value of their own initiative and hard work.

THE RELATION OF INSECT ACTIVITIES TO FOREST DEVELOPMENT AS EXEMPLIFIED IN THE FORESTS OF EASTERN NORTH AMERICA[1]

J. M. SWAINE[2]
Dominion Entomological Branch, Ottawa, Canada
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HISTORY OF THE FOREST

The Primeval Forest. Some three centuries ago, when the French and English settlers were building cabins along the north Atlantic coast, the eastern part of North America was covered by a vast and almost unbroken forest. It extended from the prairies to the sea and from the south Atlantic coast to Hudson's Bay. It comprised hardwoods of many species with conifers on the uplands in the south and conifers with fewer species of hardwoods in the north. From the tales that have come down to us and the story revealed in the forest itself we can guess at its composition. White and red pine, usually mixed with balsam fir, spruce, and hardwoods extended over an enormous area in the New England and North Atlantic states, in the provinces of Nova Scotia and New Brunswick, and in the southern portions of Quebec and Ontario. White spruce, with red spruce in the far East, usually mixed with balsam fir and often with hardwoods, occupied parts of the same area, forming dense stands on the higher ground in Maine and Southern Canada and stretching in scattered forests into the extreme north beyond the Arctic Circle. Balsam fir occurred largely in mixed forests but also in pure stands on considerable areas of the higher slopes. Jack pine grew then, as at the present time, on sandy plains and ridges, but there is probably much more of it now than there was in the primeval forest. Larch or tamarac covered swampy areas throughout the entire region and although it did not occur in extensive forests its total quantity must have been enormous. Hemlock occurred mainly in mixed stands from Southern Ontario and Southern Quebec southward. Black spruce, then as now, grew in bogs and wet places and in addition, covered a vast belt of territory stretching across the area now known as Northern Ontario and Northern Quebec. Cedar grew in large quantity on moist ground about the margins of lakes and streams. The hardwoods were more abundant in quantity and more numerous in species in the southern half of the territory; they occurred in considerable quantities, nevertheless, northward throughout the Maritime Provinces and in the southern parts of Quebec and Ontario, but only the white birch and poplars extended beyond the black spruce belt into the extreme north.

In this ancient forest there were undoubtedly many changes from time to time. Fires set by Indians or caused by lightning no doubt swept off the mature timber on areas of considerable size with a resultant change in forest types. Insect pests, such as the spruce budworm and the hemlock looper, probably ravaged portions of the forest then, as they have done in later years over larger areas, and again changes in forest types must have been the result. In the mixed forests of pine, hardwoods, spruce and balsam, there was

[1] Annual address given before the Entomological Society of America at the twenty-seventh annual meeting at Atlantic City, N.J., U.S.A., December 28, 1932.
[2] Associate Dominion Entomologist.

probably a rotation of dominant species. In the great black spruce areas of Northern Quebec and Northern Ontario, on the other hand, the conditions were probably much more stable; it is likely that a large part of that country has been covered with black spruce for many centuries and would continue so, unless interfered with by man, throughout this geologic age.

When the white man reached these shores, nevertheless, he entered a forest which in spite of certain periodic or fortuitous changes, probably had acquired a considerable degree of equilibrium and could have maintained indefinitely its general characteristics. The development of the white man's civilization has resulted in the demolition of the forest on an enormous extent of its original area and has produced directly or indirectly an extensive deterioration in the remaining timber over almost all the territory south of the black spruce belt in Northern Quebec.

The Present Forest. The result of these changes may be summarized in a few words. The original virgin forest of red and white pine has virtually disappeared. There are, so far as I know, only three considerable areas of virgin white and red pine left, one in the upper drainage basin of the Ottawa River in Western Quebec, one in the Quetico district of Western Ontario and one in the Missisaga region of Algoma in Ontario. When the white and red pine were cut, they were usually replaced by spruce, balsam fir and hardwoods, with the result that the areas on which the young stands of these pines are now growing are only a minute fraction of the original pine forest.

The original stands of nearly pure white spruce have almost disappeared, except in the northern and less accessible valleys; but there is still a considerable quantity of virgin white spruce in mixed forests which was left when the pine was cut, and which is now being utilized. The finest virgin stand of white spruce remaining in the East is to be found in the alpine valleys of the Gaspé peninsula in the province of Quebec.

Cuttings and insect epidemics in mixed spruce-balsam forests have frequently been followed by dense crops of balsam fir, with the result that on these areas the percentage of spruce has been greatly reduced while at the same time the balsam fir has increased in volume on an enormous extent of country, and it has replaced to a large degree the more valuable pine and spruce. Examples of the primeval balsam forest still remain in the higher or less accessible areas; one of the finest is to be found on an upland plateau in the extreme north of Cape Breton Island. Hemlock was utilized extensively in the past for tan bark and the old trees are found now chiefly about pleasure resorts. A splendid stand of virgin hemlock still remains uncut in the centre of Nova Scotia, north of Lake Rossignal, a perfect fairy land of forest beauty. Larch virtually disappeared from our Eastern forests as a commercial tree many years ago, swept away by repeated attacks of the larch sawfly. Today, a younger crop of larch is growing on an area that is possibly somewhat reduced in extent. The great black spruce belt across Northern Quebec and Northern Ontario still exists, although greatly reduced in area by lumbering, by extensive fires and by settlement along the transcontinental railway. Jack pine will always remain on sites of poorer soil and its total volume has been greatly increased in recent years as the result of numerous fires and lumbering. Cedar has been cut out to such a degree that very little is left of commercial size in the northern and northeastern sections.

The hardwoods have undergone many changes, but they cannot be described here in detail. The species with a present high commercial value have been greatly reduced in volume throughout the Canadian zone, while in the mixed forests of the same region birch and poplar have increased greatly in volume as a result of fires and lumbering.

The magnitude of changes on so vast a scale may be appreciated better by considering the history of the forest on a particular area. The Ottawa River drainage basin comprises an enormous extent of country all of which was originally covered with forest. The upper or western portion is still a forested country although the greater part of it has been cut over several times for lumber or pulpwood; the lower portion is an agricultural section, with many scattered towns and villages. Furthermore, the nature of the original forest and the history of the lumbering operations on the area are recorded with some degree of accuracy. The history of the forest in the Ottawa Valley, therefore, should illustrate fairly well the general situation.

The Ottawa River drains an area of 35,416,000 acres of which about 28,000,000 acres are, or were, productive forest land. The original stand of saw timber is estimated to have been at least 500 billion board feet (about 125 times the present annual cut in the whole of Canada). It is believed that at least one half of this timber (250 billion board feet) was white and red pine; 45% (225 billion feet) was spruce, balsam and other softwoods, and 5% (25 billion feet) was hardwood. The present stand is estimated to consist of not more than 10 billion feet of white and red pine, 5 billion feet of other softwoods, and 4 billion feet of hardwoods, a total of 19 billion board feet (*1*).

In addition, there are perhaps 40 million cords of softwood and 25 million cords of hardwood of smaller sizes suitable for pulpwood, ties, posts, fuel, etc., or the equivalent of a little over 50 billion board feet of all sizes. The records which are available indicate that during the last 120 years the amount cut for use has been between 35 and 40 billion board feet. The balance, some 410 billion feet, has been destroyed, chiefly by forest fires, land clearing, insects and fungi (*1*).

In effect, the forested area of the northeastern portion of North America has been reduced in extent to an enormous degree and the timber values have been largely dissipated on a great proportion of the forest land that remains. Instead of the big timber of the past, we have small trees, species of lesser value, thousands of miles of pure forest land on which repeated fires have exterminated all species of commercial importance, and, in general, a forest which is at best hardly holding its own against the agencies which are still operating to destroy it, and containing timber supplies which will probably be insufficient for the needs of the next generation.

Nevertheless, there is still a great quantity of commercial timber in Eastern North America and a large amount of young growth which, if protected, will be invaluable in the future. There is still a great forest, one that is well worth protecting, and one that will yield vast returns if it receives the care from this generation that it deserves.

Destructive Agencies

The destruction of timber has resulted chiefly from five causes; the activities of the settler and lumberman, from fires, insects, fungi and from windstorms and heavy snow. The deterioration in the remaining forest has

been occasioned through the change to less valuable timber species following fires, cutting, and insect outbreaks; through unhealthy conditions produced in the remaining stands by cutting, and through the effects of injury by insects and fungous diseases. In this connection, it should be noted that many of the more destructive forest insects in the country have been imported from Europe through the agency of man, and the injury they have caused must be charged against man's activities.

Insect activities. In this reduction of the original forest, insect life has played a very prominent rôle, and one that has become increasingly important during recent times. It is, however, only one phase of forest insect activity. Insects which are considered "primary" enemies feed upon some part of the living tree and are potentially destructive. Most of the primary species cause little actual injury beyond an occasional severe pruning; some are notoriously destructive and periodically occur in great outbreaks, whilst other species, usually of little or no economic importance, suddenly appear in widespread infestations. A second great category of forest insects includes "secondary" enemies, since they attack only dying or dead trees or wood products. In so far as commercial values are concerned, some of these species cause a vast amount of loss—sawyer beetles and others in fire-killed timber and saw logs and in log buildings, for example, or powder post beetles in stored wood products. In so far as the health and wellbeing of the forest is concerned, however, the "secondary" species are of importance chiefly as scavangers and are either beneficial or neutral in their effect on forest development. It is probable that the activities of many secondary species are extremely beneficial to the forest in hastening the death of overmature and weakened trees and thus liberating the young growth and also in accelerating the destruction of the debris on the forest floor. It is obvious that the destruction of the debris is essential to the health and natural development of the forest, particularly in facilitating the growth of seedlings and in providing plant food and a moisture-retaining layer of duff over the forest floor.

The most impressive effect of insect activities in the forest is the destruction of timber wrought by great epidemics of the primary species. There might be recorded a long list of major pests which have contributed their considerable part towards the destruction of the primeval forest; but only a few of the most destructive species have been selected to serve as illustrations and they have been confined largely to those affecting coniferous trees.

The Spruce Budworm (*Cacoecia fumiferana* Clem.). Perhaps the most striking example of insect destruction in the forest is afforded by the great spruce budworm outbreak of the last generation, which extended eventually over an enormous territory including the state of Maine and all Eastern Canada from the Atlantic Ocean to Central Ontario south of the great black spruce belt. It did not spread down the North Shore of the Gulf of St. Lawrence, and for some unknown reason it missed the Gaspé peninsula; but it missed very little else in all that vast territory, where balsam fir was growing.

The ravages of the budworm during the last 20 years, in which such enormous quantities of timber were killed, probably constituted the most destructive forest insect outbreak that has ever been recorded. It has been estimated that in Eastern Canada alone more than 200 million cords of balsam and spruce were destroyed. The vast amount of this loss can be

better appreciated by comparing it with the losses caused by fires. It has recently been estimated by one of our most competent foresters that fires have destroyed balsam and spruce in Eastern Canada during the last 20 years to the amount of approximately 70 million cords (*1*). The spruce budworm alone destroyed three times as much.

The adult insect is a small brownish moth which appears in July and lays its eggs on the needles of fir, spruce and hemlock. The caterpillars which hatch from the eggs go immediately into hibernation in minute silken cases on the twigs. In the following spring they appear when the balsam and white spruce buds are opening and feed upon the buds and young foliage, avoiding the old needles until the young twigs are destroyed. Balsam fir and red spruce are injured most severely, white spruce usually to a lesser degree, and black spruce is usually immune from very serious defoliation. After two or three years of severe injury, the older stands of balsam and red spruce begin to die and in the overmature stands the mortality may attain more than 90%. The younger and thrifty stands of balsam fir are usually able to survive without serious injury and on this fact the recommendations for control are based.

During the last generation, lumbering, fires and insect outbreaks have resulted in augmenting to an enormous degree the original quantities of balsam fir, and this tree will have a very prominent place in the pulpwood industry of the coming generations. In the forests of New Brunswick, for example, one effect of the spruce budworm outbreak was to increase the percentage of balsam fir from about 50% in the old stand which was killed to 85% in the young crop which is now growing up (*2*). If great areas of balsam fir are permitted to become overmature, another and even more destructive spruce budworm outbreak may eventually be expected. On the other hand, if the remaining overmature stands are utilized and the young balsam cut on a short rotation, the forest should become very largely immune to destructive budworm outbreaks.

The Larch Sawfly (*Lygaeonematus erichsoni* Hg.). The larch or tamarac sawfly is a most destructive enemy of the American larch. The larvae feed upon the foliage, which may be more or less completely destroyed, and they go into hibernation in silken cocoons on the ground beneath the trees. It is possibly a European insect which was brought into this country in some unknown way, probably more than 100 years ago. A reference to an insect defoliating larch, published by Audubon in 1835 and recording an outbreak which occurred 25 years before, may possibly refer to this insect (*3*). The species was apparently described from Massachusetts, under the name *Nematus notabilis* Cresson, in 1860, but it was not reported as a widely distributed and injurious insect until about 20 years later. In the years immediately following 1880, the sawfly developed into a tremendous outbreak extending throughout all Eastern Canada and the New England States from Nova Scotia and Maine to the Great Lakes. By 1890, nearly all the larch of commercial size in Eastern Canada had died as a result of this attack. More recently, the outbreak has spread westward past the Great Lakes and north of the prairies into British Columbia and the Yukon, so that the sawfly now covers almost the entire range of the eastern larch.

The young stands of larch which have grown since the original outbreak occurred are now approaching commercial size. The sawfly has been varyingly abundant on these young stands, but not to a destructive degree, and during the last few years its numbers have been greatly reduced. In the years 1911, 1912 and 1913, a European parasite of the larch sawfly (*Mesoleius tenthredinis* Morley) was imported into this country from Britain and distributed in several places in Eastern Canada and Manitoba. This parasite has become established and has recently been recovered as far as 200 miles from the place of liberation. An attempt has been made to spread the parasite more widely in Eastern Canada, but during the last 10 years there have been no larch sawfly outbreaks in Europe from which they could be obtained, and for the last two years there have been none in Eastern Canada.

How much the imported parasites have had to do with reducing the numbers of the sawfly cannot yet be determined. It is possible that native parasites may have recently become more effective.

The Larch Case-bearer (*Haploptilia laricella* Hb.). For the past three years another defoliating insect, also of European origin, known as the larch case bearer, has spread in a severe infestation on larch stands throughout the eastern forest from Nova Scotia and Maine to Central Ontario. The needles are mined and killed by the small caterpillars and the outbreak has been so intense that in 1932 apparently most of the larch from New Brunswick to Algonquin Park in Ontario was almost completely defoliated. After the foliage has been destroyed by the caterpillars a second crop of needles is produced, and on this account previous outbreaks have not proven to be destructive. The present outbreak by the case-bearer, however, is apparently the most severe that has ever been experienced in this country, and it hardly seems possible that the trees could long withstand such severe attacks uninjured.

The Eastern Hemlock Looper (*Ellopia fiscellaria* Guen.). In the years 1925 to 1928, defoliating caterpillars known as the eastern hemlock looper, destroyed a large amount of hemlock in Wisconsin, Minnesota and Central Ontario. In the Lake States the same species attacks balsam fir, and it has long been known as a destructive enemy of that tree on the island of Newfoundland. In Ontario, however, in so far as we know, the looper has confined its attacks to hemlock, and until recently this had apparently been the case in the province of Quebec. In the year 1928, extensive outbreaks on balsam occurred on the North Shore of the Gulf of St. Lawrence. The outbreaks lasted for three years and disappeared. More than 100 square miles were affected in three large river valleys.

In 1929, an airplane dusting operation was carried out on one infestation and the caterpillars were almost completely destroyed. The outbreak subsided in another valley in 1930 and in the third a year later. Cold wet weather in early summer apparently was effective in destroying great numbers of the young caterpillars in the last two outbreaks, and may have been the chief influence in reducing the outbreak in those districts.

Bark-beetles. An extraordinary amount of injury has been caused in North American forests, particularly in the West, by the small beetles known as bark-beetles. Although many species of these insects occur in eastern forests only a few are of primary importance. The chief of these is the

eastern spruce bark-beetle (*Dendroctonus piceaperda* Hopk.) which is now causing extensive injury in the Gaspé peninsula of Quebec.

The brown or black beetles, one-third of an inch long, breed only in the bark of spruce, chiefly in white spruce and red spruce. The vertical egg-tunnels, four to six inches in length, are cut between the bark and the wood on the trunk of the tree. In living trees the flow of sap is quickly checked and the death of the tree results very rapidly. Under normal conditions in the forest this species breeds in weakened or dying trees, in windfalls and in logs; but when their numbers become very great they readily attack and kill healthy trees and they have in the past destroyed large quantities of the finest white and red spruce in the eastern forests. Their outbreaks appear to have a certain periodicity, and we are now experiencing a series of attacks by this species in the forests of Quebec and in the Maritime Provinces.

The Balsam Woolly Aphis (*Dreyfusia piceae* Rtzb.). A species of bark infesting aphis, known as the European balsam woolly aphis, was imported from Europe into Eastern North America many years ago. It has been found affecting balsam fir in the Maritime Provinces and in several places in the Eastern United States, but it has increased most abundantly in Nova Scotia, New Brunswick and Maine. It is now spreading northward through New Brunswick and will possibly become distributed eventually throughout the balsam forests of Eastern North America. The insect is a minute plant louse with the body covered by white, wool-like, wax threads; it lives on the bark of the trunk or twigs and sucks the sap through the long slender beak which penetrates deep into the bark. When the insects are abundant, wool-like patches appear on the trunks of balsam fir, the only tree on which it occurs. This species kills the trees directly, but the most serious effect of its feeding occurs on young stands in which it produces a malformed growth, called the balsam gout, that may completely ruin or even kill the trees. In European forests this species is not considered to be of major importance, and it is evident that the North American balsam (*Abies balsamea* (L.) Miller) reacts much more strongly to the insects' attack than do the European species, both in regard to the injury to the trunk and to the malformation of the young trees and growing tops. The form affecting the buds and twigs has been distinguished in Europe under the name *D. piceae* var. *Bouvieri* Chol., and its effect on exotic species of *Abies* is said to be more serious than it is on native European species.

Certain species of agromyzids are being brought from Britain for distribution in the Maritime outbreak.

The European Spruce Sawfly. In 1930, a large area of white spruce in the Gaspé peninsula was found to be affected by a defoliating sawfly larva which was subsequently determined to be *Diprion polytomum* Hartig, a native of central and southern Europe where it is of but little economic importance. It is assumed that the insect has been introduced into this country sometime during the past generation. Although so abundant in the Gaspé, this sawfly has never been recognized elsewhere in Eastern Canada, except that one specimen collected near Ottawa in 1932 is now believed to belong to this species. Several specimens were taken in Maine in 1931 and in 1932 and it was recorded from one other locality in the New England States in 1931.

Biological investigations, ground surveys and an aerial survey were carried out on the Gaspé outbreak in 1931. The infestation then covered the

entire central area of the peninsula, with the severest degree of attack confined to the upland valleys of the interior. In 1932 the outbreak continued in severity in the central area and increased over a considerably extended range. In the most heavily infested valleys, the white spruce is now severely defoliated, with a noticeable retardation in growth extending over about four years. There is little doubt that much of the timber is badly weakened, although only a very few trees have yet been killed by the sawfly. There is every reason to expect that the outbreak will continue, although with less severity, in 1933, and the black spruce is now being attacked in some places as readily as is the white spruce. The larvae feed only on the old foliage, leaving the young twigs of the current year practically untouched, and this fact probably explains the ability of the trees to withstand the defoliation. The larvae hibernate in cocoons on the ground beneath the trees, and during the last two years considerably more than 50% of the cocoons have carried over the summer to the following year. This habit is of particular importance inasmuch as mice and shrews have thereby a continuous opportunity to feed upon the larvae. During the past two years these animals have destroyed more than 40% of the hibernating cocoons and they are at present the most important factor in control. Only a few parasitized larvae have been found. Males are practically unknown, a fact which is probably significant in connection with the rapid increase of the outbreak.

During the past summer an effort was made to obtain parasites of this species in Central Europe and a supply will be available for distribution in the Gaspé outbreak in the spring of 1933. Inasmuch as native parasites have not yet attacked the sawfly, the introduction of the original parasites from Europe should prove to be beneficial; it is at all events the only forward step toward control that appears to be feasible at the moment. It has been determined that the sawfly succumbs readily to calcium arsenate and we have learned how to dust forests by airplane. When financial conditions become more favourable, airplane dusting may be employed to protect the most valuable stands.

The Black-headed Budworm. In the summer of 1929, a large area of balsam forest, some 200 square miles in extent, in the southern part of Cape Breton island was found to be heavily infested with caterpillars of the black-headed budworm (*Peronea variana* Fern.), a species with a method of feeding closely similar to that of the spruce budworm. The species had previously been exceedingly rare in Eastern Canada, only a few specimens having ever been collected. In 1930, some 500 square miles of territory were covered by this infestation; in 1931 the larvae were reduced to one-tenth of the number in 1930 and the infestation subsided at the end of the season; in 1932 it has practically disappeared.

The European Beech Scale (*Cryptococcus fagi* Barensp). The European beech scale is a minute sap sucking insect covered with wool-like wax threads. It feeds on the bark of beech, whose trunks become covered with wool-like patches of the insects when the latter are very abundant. When followed by certain bark infesting fungi (*Nectria*) this species is very destructive to the American beech. It was introduced into Nova Scotia many years ago and has since spread throughout all parts of that province and throughout the southern part of New Brunswick, causing a very heavy mortality in beech

stands. It occurs also in the New England States, although not yet in Quebec or Ontario. It will probably kill a large proportion of the beech in parts of Eastern North America where the species of *Nectria* which can follow it happens to be present.

The examples that have been presented include a few of the most injurious and more interesting of the major pests of the eastern forests, but the list could be extended to include many species, some of which, like the white pine weevil, are perennial in their depredations, whilst others spring into importance only at long intervals as the cause of extensive infestations.

Indirect Effects of Insect Injuries. An important effect of insect outbreaks is the reduction in the growth and health of the affected timber. Even though little actual mortality be caused, an extensive infestation may result in an enormous unseen loss through the reduction of diameter and height growth in the timber as well as in an unthrifty condition of the stand. The present great outbreak of the larch case bearer can hardly fail to produce such an effect. Judging by investigations made in Maine, Connecticut and New Brunswick, the infestations of defoliating insects, *Bucculatrix canadensisella* Chamb., *Phyllotoma nemorata* Fallen, and *Fenusa pumila* Klug, on birch, which now extend from the Atlantic coast to the Great Lakes, have already produced both these results, particularly in the Atlantic coast region where the injury has persisted longest and has been most severe. The spruce budworm outbreaks caused an enormous loss in the reduction of diameter growth in stands which eventually recovered a fair degree of health.

When one considers the total mortality in the forest caused by the major insect enemies and, in addition, the depreciation in forest values caused by changes in forest composition following insect outbreaks, and the reduction in growth and health of the forest which has resulted directly or indirectly from insect damage, it becomes apparent that the effects of insect attack on the forests of Eastern North America have been tremendously injurious and that the prevention and control of injuries caused by forest insects constitute a problem of vital importance in forest protection.

Interrelations between Insects and the Forest Environment

The investigation of great forest insect outbreaks is continually extending our knowledge of the relations between the insects and their forest environment. An investigation of this kind may include within its scope the study of a large part of the forest complex, together with the climate and soil conditions of the district. The interrelations of the insects with any of the other components of the forest or their responses to climatic or other environmental factors may be intimately concerned with the progress of the insect epidemic, or in a more general way, may affect the health or development of a portion of the forest itself. The present discussion of these relationships and of the factors which influence the economy of forest populations must necessarily be very brief, but some of the problems involved therein are of great interest and importance in any general consideration of forest development.

A thousand fascinating relationships exist between the insect fauna and the other life of the forest, between the insects and their host plants, their insect parasites and predators, the birds, mammals and other animal life and the fungi.

Insects and Their Host Trees. Some insects feed on only one or a few closely related species of trees, whilst others readily attack a wide range of host plants; some attack bark or wood only when it presents certain definite physical or chemical characteristics and others appear to be much less particular in their choice; some species follow their host trees throughout the latter's range on the continent and other species are confined by climatic or other factors to a comparatively narrow area. The destruction of great quantities of a primary host in a region may result either in the virtual disappearance of an insect species or in forcing it to concentrate on secondary hosts.

Insect Parasites. The relations of forest insects to their parasites have received a great deal of study. Many attempts have been made to effect the control of introduced pests through the introduction of their native parasites. Successes and apparent failures have attended these efforts, but certain of the successful ventures have been so impressive that this method of establishing a natural control for introduced insects is being generally applied. In addition to the specific parasites of the introduced pest, it may sometimes be profitable to import the same species of parasite or even different species with suitable life-histories from other species of hosts. An interesting situation is now appearing in that parasites which were established in a district for the control of an imported insect are proving to be of service in checking the subsequent invasion of other species.

The utilization of native parasites through their multiplication and distribution for the control of outbreaks of native forest insects has received much less attention. Some extensive outbreaks of native defoliating caterpillars have evidently been controlled by parasites, and the possibility of utilizing parasites in such cases should be further explored; but in the case of many serious forest infestations the degree of parasitism has rarely become high enough to be considered of great importance. The effect of parasitism with many forest species is probably to check the multiplication of the host beyond the endemic condition and to lengthen the time between outbreaks.

Insect Predators. The insect population serves as a necessary food for birds and mice and even for fish in the lakes and streams. On the other hand, both birds and mice exert a certain, if usually minor, controlling influence on insect multiplication. Woodpeckers, for example, have destroyed as much as 90% of the broods of *Dendroctonus piceaperda* in small outbreaks. They are probably effective at times in controlling sporadic outbreaks and in hastening the decline of more extensive ones, although they are usually of little importance at the height of great infestations. Mice and shrews destroy large numbers of insects which hibernate in the debris on the ground surface. These animals have apparently been helpful, for example, in reducing some larch sawfly infestations and during the past two years they have destroyed approximately 40% of the hibernating larval cocoons of the European spruce sawfly in the Gaspé peninsula. Spiders, ants, wasps, syrphus flies, clerid and carabid beetles, and others are sometimes of local importance in checking the increase of injurious forest species.

Forest Insects and Fungi. Forest insects and fungi have many interrelations. Insects are sometimes responsible for facilitating the invasion of the bark and wood which they attack, by species of parasitic fungi. Such a

relation exists between *Cryptococcus fagi* Baren. and the *Nectria* which follows its attack on the bark of beech and which eventually kills the trees. On the other hand, entomophagous fungi and other organisms are sometimes effective in destroying many insects and may even become an important factor in the control of rather extensive outbreaks.

A very interesting association between certain bark-beetles and fungi causing blue stain in the trees attacked by the beetles has been brought to light recently on this continent by the studies of Dr. Craighead and Dr. Rumbold (*4*). It has been demonstrated both in Europe and in America that where they are introduced artificially into the inner bark and cambium the fungi are able to kill the trees without the aid of the beetles. It is probable also that some species of *Dendroctonus* would kill the trees without any assistance from the fungi. It remains to be proven whether the beetles or the fungi receive the greater benefit from this partnership. These studies have opened a field of great scientific interest and with possibilities of application in practical control.

It is apparent that the tunnels of bark and wood boring insects must aid in introducing the spores of wood rotting fungi into stumps, fallen trunks and other debris on the forest floor, but there is little exact information yet available on this subject.

A remarkable case of symbiosis exists between certain wood boring beetles, known as ambrosia beetles, and definite species of fungi, called ambrosia fungi, which invariably accompany the beetles in their tunnels, clothing the tunnel walls with a luxuriant growth of conidiophores during the time the larvae are developing. A few of these beetles attack living trees and are of some importance in the forest economy; *Corthylus* for example injures hard maple seedlings, and several species on this continent are injurious to commercial timbers. These fungi, therefore, upon which the beetle larvae are solely dependent for food, also play a definite part in the forest development.

The ambrosia beetles excavate slender tunnels deep into the wood of the trees they inhabit. The hyphae of the fungus penetrate the cut cells and the vessels for several millimeters and eventually stain the tunnel walls dark brown or black, but they cause no other injury to the wood. The forest of conidiophores which projects into the lumen of the tunnel, in the case of many species, serves as the sole food of the larvae and forms an important food of the adult beetles. On the other hand, these species of fungi have been found *only* in the tunnels and in the alimentary canal of the beetles. A perfect case of symbiosis appears to have been established.

Shortly after the tunnels have been commenced, germinating thick-walled spores are found on bits of excrement on the walls of the tunnels, and the hypae, growing rapidly, produce vertical chains of conidia which ripen terminally as large *thin-walled spores.* These latter are distributed by the beetles over the tunnel walls as fast as the excavation proceeds and, germinating rapidly, they give rise to hyphae which rapidly cover the tunnel walls with a dense forest of erect conidiophores like the pile on velvet. The thin-walled spores of the species I have studied go through the conidial cycle in drop cultures in about 60 hours. Within a very few days the production of thin-walled conidia ceases and thereafter only the thick-walled spores are

produced. The latter will germinate, apparently, only after having passed some time in the alimentary canal of the beetle. Several genera and a considerable number of species of these fungi accompany the ambrosia beetles of North America, but none has yet been described. Many interesting relationships exist between different species of beetles and the particular food fungus which accompanies them. A somewhat similar fungus association is found elsewhere among insects, notably with certain gall-making species and in the coleopterous family *Lymexylidae.*

Factors Influencing Outbreaks

One of the most important inquiries before entomologists today concerns the causes which influence the rise and fall of great insect outbreaks. Definite facts have been learned respecting the decline of a few insect epidemics in the forest, but too little is known of this subject as yet to justify much generalization.

Forest epidemics are usually well advanced before the entomologist has an opportunity to commence his studies. It has rarely happened that a great forest outbreak has been investigated throughout its full course, and it is partly owing to this situation that our knowledge of the factors affecting the rise of outbreaks is even more meagre than that of those causing the decline. There is much valuable information to be gained by an intensive environmental study of injurious species throughout the complete outbreak cycle, from the peak of one outbreak throughout the years until the peak and decline of the next.

The causes behind the rapid increase or decrease of insect populations must usually lie in the field which has been termed, very aptly, the "environmental resistance." There are at present two great difficulties in dealing with this matter, one being our lack of knowledge of definite facts, and the other that many of the factors may change very greatly from one outbreak to another and from one season to the next.

It is probably too early to make definite statements regarding the constancy of the factors in the biotic potential, but it is very apparent that those of the environmental resistance vary so greatly that it is useless to attempt an estimation of the total resistance in the case of a field problem from data obtained in a previous investigation.

Some forest species are probably held in check effectively by parasites and predators. Some outbreaks of forest tent caterpillars have been controlled by flacherie, and others by a combination of parasites and fungi. On many occasions native parasites and diseases have been among the most evident factors in controlling severe outbreaks of certain forest insects, and they appear to be responsible, in some cases in large measure, for producing the phenomenon of periodicity in connection with infestations.

Climate and Weather. The influence of weather and climate in regulating the distribution and the activities of insects is of great importance. Forests, in general, have climatic characteristics which differ in many respects from those obtaining in the open country. The work of Lorenz-Liburnau and others in Europe and that of Fernow and Zon in America has brought out many features of the forest climate which are gradually being applied to the study of insect life in the forest. Whilst the general effect of the forest cover

is one of moderation and equalization of extremes, there are several phenomena peculiar to forest conditions which appear to have a special significance. Such are the reversal of temperature gradients in the spring and fall, the increased precipitation over forested areas, and the retention of humidity under the forest cover. This study is still in its infancy but it holds considerable promise for the explanation of such insect activities as the vertical distribution of species, migration into and out of the forest, and variations in life-history and habits.

Differences in light and in air circulation appear to have a marked effect on many species. In many instances, particularly in the study of boring species, the micro-climate requires thorough investigation. Undoubtedly insects have become inured, to some extent, to many fluctuations in weather conditions, but these fluctuations are often sufficiently great to produce significant effects on density of population, local distribution, or modification of life activities.

Many outbreaks of defoliating caterpillars have apparently been controlled by cold, wet weather affecting the first few larval instars; or by heavy beating rains at the time of pupation, after the protecting foliage had been destroyed; or by starvation through exhaustion of the food supply; or by certain other conditions which have been fairly well established in the cases of definite outbreaks. On the other hand, peculiar climatic conditions may favour the development of great insect outbreaks. The appearance of extensive bark-beetle infestations following periods of excessive dryness is a case in point.

Changes in Species Virility. The epidemic of the black-headed budworm in Cape Breton island, already mentioned, presented interesting features in connection with the cause of its decline. The outbreak was discovered in 1929 on some 200 square miles of territory. The infestation was so severe that the trees were reddened over a large part of this area, although an inspection of the same district in the previous summer had disclosed no such injury. It is evident that the outbreak developed with great suddenness and apparently in one season. In 1929 the eggs were extremely abundant, although the average number laid by the females was not ascertained. In 1930 the outbreak had spread over almost 500 square miles; but, although the moths were very numerous, they laid very few eggs either in the open or in the cages, the average per female being only about six in the several conditions under investigation. In 1931, the infestation was reduced to somewhat less than one-tenth the numbers of 1930, and parasites and disease destroyed the caterpillars so extensively that an average of less than one moth per tree was obtained on the areas studied. In 1932, the outbreak had disappeared and no trace of fresh defoliation could be found.

It is a temptation to speculate with even these meagre data. If the oviposition average in 1928 and 1929 had been 100 or more (which may very well have been the case since dissection showed the females to be capable of laying as many as 150 eggs and it is known that the oviposition in 1929, at least, was extremely heavy) the evident decrease in the oviposition of the females over a large extent of territory would explain the rapid decline of the outbreak. The weather conditions of that district during the spring months

of 1927-1929 varied only very slightly from the normal and could hardly have affected oviposition to any marked degree.

The comparison by J. J. deGryse (unpublished report), of a large amount of carefully compiled data obtained during three years succeeding the peak of an outbreak of the maple leaf cutter (*Paraclemensia acerifoliella* Fitch) shows a yearly increase in the general debility of the strain. The eggs, although normal in the average number laid per female, showed a yearly decrease in the number hatching. The larvae showed a yearly increase in mortality while in the mine, a very definite yearly increase in the length of the second stage—and this in an increasing percentage of individuals—a similar progressive increase in the length of the third and fourth stages, with, as an ultimate result, a high percentage of mortality which appeared to be due solely to congenital weakness. This weakness was further manifested throughout the life of the individual by a lack of ordinary activity, such as slow and irregular feeding.

The suggestion is made in a report (unpublished) by Norman Criddle and R. H. Handford concerning a recent outbreak of the Bertha armyworm (*Barathra configurata* Walk.) in Manitoba that the sudden termination of the outbreak appeared to be accompanied by a somewhat similar decrease in virility.

This insect, which had been of local annoyance in Saskatchewan for a number of years previous to 1927, began in that year to increase in Manitoba, and by 1929 it had become so abundant that large areas of sweet clover and flax were destroyed. Its activities at this time extended from Manitoba and North Dakota to British Columbia. Then, in 1930, after hatching in large numbers, the species suddenly dropped into insignificance. At the Treesbank laboratory a study of the insect was being made at the time and a number of larvae were under observation, most of which had been reared from the eggs. The eggs proved to be mostly fertile and definite numbers of larvae were obtained and fed on sweet clover, one of their favourite food plants. They were reared under similar conditions to others which had reached maturity in 1929, yet despite every attention these larvae all perished. A few died in the first instar but most of them survived until the second or third stage. As they increased in age they steadily became more sickly, extended on beyond the period of normal moulting and finally died. This behaviour occurred not only in the laboratory but observations in the field showed that the larvae were behaving there in a similar manner and finally the entire outbreak collapsed. Scarcely a larva was present in 1931.

It should be added that while both parasites and diseases were present, these in combination did not account for more than 20% of the larvae. Thus the rapid subsidence of the outbreak seems to have been wholly due to a physical weakness in the larvae. Whether this weakness was brought about by weather or by some other factor or a combination of agencies was not determined.

The subject of virility of the strain is exceedingly complex and offers apparently a promising field for research. There is the possibility, particularly following the peak of an outbreak, of a subnormal sexual fertility appearing in either sex which may be disclosed by a reduction in the number of fertile eggs laid by the females, or a congenital weakness which may result in egg

mortality and lengthening of the larval stages with greater susceptibility to disease and higher mortality. The same final results have evidently been caused by inclement weather conditions. The question of a reduction in the virility of bark-beetle broods during the latter part of an outbreak has been the subject of investigation recently by European workers, and data on the same subject are being collected on this continent. A sudden increase in virility, on the other hand, may be a major factor in the sudden rise of some outbreaks.

Food Supply. The abundance of a suitable food supply is obviously necessary before a great insect infestation can develop, but vast supplies of the preferred host of an insect have existed for long periods before very extensive trouble of this kind has developed. Under such conditions, small outbreaks have occurred here and there over the forest during long periods and suddenly, from several distant points of origin, a series of outbreaks has developed and in some instances merged into a great infestation. This is, in effect, the history of the spruce budworm outbreak of Eastern Canada and Maine. There was unquestionably a vast food supply of balsam fir in the forest regions between the Atlantic Coast and Central Ontario. Extensive cuttings and fires during the previous generation had favoured the increase of balsam over the southern part of this area; but that could hardly be said of the northern portion, and it was in the north, between Lake Expanse and Lake Manawan, in northern Quebec, that the earliest outbreaks are supposed to have occurred.

During the previous century, a series of budworm outbreaks, some of them of considerable size, had occured in the forests of Maine, New Brunswick and Southern Quebec, but there are no records for that period from Northern Quebec and Northern Ontario. There was an immense amount of balsam fir in the Gaspé peninsula and along the North Shore of the Gulf of St. Lawrence, yet the budworm outbreak did not develop in either place. The extensive upland plateau in northern Cape Breton island has carried a pure stand of balsam, probably for countless ages, and yet, although the budworm occurs in that stand and has even been reported as rather abundant at times in the northern portion, no budworm outbreak of any importance has left any record of its occurrence in that area.

The hemlock looper is a common insect in the forests of New Brunswick and Nova Scotia; both balsam fir and hemlock occur there abundantly, and the climatic conditions are probably more favourable there than in Newfoundland or on the North Shore of the Gulf; nevertheless no important outbreaks of this insect have been reported from the Maritime Provinces for many years.

The food supply, such as extensive pure stands or rich mixtures, is a pre-requisite for an outbreak, and under our forest conditions such stands are constantly in danger, but the cause of the outbreak must be sought elsewhere.

The Influence of Forest Types. The abundance of forest insect epidemics in recent years has been ascribed sometimes to the alterations in forest types which have resulted from man's activities. On this continent so much injury has occurred in virgin stands and in both mixed and pure stands which have resulted from cutting operations, that the planted and managed forests of Europe have been looked on with envy in the past in the belief that they were less susceptible to insect attack. On the other hand, European forests have

suffered so severely from insect depredations that foresters and entomologists in Central Europe formed the opinion that their insect troubles were due largely to their artificial and managed forests and for a time they thought with envy of our virgin stands and mixed forests as being immune from great insect outbreaks. Large areas of forest containing only one or two species are considered to favour the development of outbreaks by certain insects and, other things being equal, it will probably be best to encourage the growth of mixed forests in so far as management can effect it. It should be noted, however, that overmaturity of the stand has been responsible for much of the mortality during recent insect outbreaks in pure stands, and, also, that there has been some evidence that insects which usually inhabit pure stands by preference may be able to adapt themselves readily enough to the conditions in a mixed forest. There is probably little reason to have much confidence in the general immunity of any type of stand, although certain types certainly have an advantage with respect to particular insect species.

A rather peculiar case of natural protection has occurred in a larch forest north of Belleville in Ontario. This forest is more than a mile long and nearly as wide, and is composed mainly of larch growing in a wet alder swamp. The water table is at the ground level throughout the year, except for a short period in midsummer, and for that reason larch sawfly cocoons have probably not been able to hibernate successfully. The trees vary in age in the main stand from 90 years to 216 years, and consequently they have escaped completely the larch sawfly outbreaks. A similar case has been reported from Eastern Manitoba and Graham has referred to other instances observed in the Lake States.

Groups of Outbreaks. It is somewhat peculiar that several or many outbreaks of the same species of insect sometimes arise at nearly the same time on widely separated areas. The spruce budworm outbreaks have already been mentioned. The outbreak of the black-headed budworm (*Peronea variana*) in Cape Breton island, was paralleled by an outbreak of the same species on the coast of British Columbia and in parts of Western United States. The series of outbreaks by the hemlock looper at nearly the same time in the Lake States, Ontario, and the North Shore of Quebec, already described, and recent outbreaks of the Douglas fir tussock in Western United States and British Columbia afford other striking examples.

The eastern spruce bark-beetle (*Dendroctonus piceaperda*) appears in outbreaks, periodically, from the Atlantic Coast to Northern Alberta. Two such periods of infestation are recorded and several others are to be inferred from the older records. In the last instance outbreaks occurred in the Gaspé peninsula, Nova Scotia, New Brunswick, Central Ontario, Manitoba and in Northern Saskatchewan, all within a few years of each other. At the present time there is an extensive outbreak in the Gaspé peninsula and smaller infestations in parts of Nova Scotia, although for the previous few years there had been no outbreaks reported. If history repeats itself in this instance, we shall discover outbreaks of this beetle in Ontario, Manitoba and Saskatchewan within the next two years.

For the last few years there has been an unusual abundance of various sawfly species in Canadian forests. The larch sawfly was increasing in the East until two years ago and has since declined; the spruce sawfly of the

Gaspé is a new occurrence; there have been three hitherto unknown species of jack pine sawflies concerned in an extensive outbreak in Central Ontario and a new species had just before been recorded defoliating jack pine in Minnesota; the fir sawfly occasioned the most extensive outbreak ever recorded in Canada for that species in the Sault Ste. Marie district in 1930; an undescribed species of sawfly has been defoliating hemlocks in Queen Charlotte islands for the last two years; and a considerable number of other species might be added to the list. Climatic conditions in these widely separated regions are so diverse that they could hardly favour the development of the same insect at so nearly the same period of time, and in any case, how shall we explain this extraordinary plague of sawflies?

Periodicity. Certain of our well-known forest insects have appeared in extensive outbreaks at more or less regular intervals. The tent caterpillars, the fall webworm, and the birch leaf skeletonizer will serve as examples. During the last 40 years, extensive outbreaks of the birch leaf skeletonizer have occurred in the forests of Eastern Canada at intervals of almost exactly 10 years, and have lasted approximately three years before subsiding. In the case of some insects, the parasites, predators and diseases appear to play a part in maintaining this periodicity; with others the outbreaks may be dependent on the development of a new food supply, either through growth or by the overthrow of timber in windstorms, or by other causes which may present a measure of real or apparent regularity.

A striking correlation has been shown by Criddle (*5*) to obtain between sun spot maxima and the greatest abundance of both grasshoppers and grouse on the Canadian prairies during the last 40 years. The possible relation between the sun spot phenomena and insect abundance is evidently deserving of a much wider investigation than it has yet received.

No combination of the known agencies appears to be sufficient to explain all the phenomena involved in the development of groups of outbreaks and periodicity, and it is possible that there is some factor influencing the rise of great insect outbreaks that has not yet been discovered.

In the whole field of Entomology there is probably no subject of deeper scientific interest or of greater practical importance than the general question of the causes underlying the appearance and progress of great insect epidemics. Hidden among its secrets are the possibilities of forecasting outbreaks and taking measures for their prevention or mitigation, predicting their progress and providing for control or salvage, and laying intelligent plans of management for obtaining a measure of insect immunity.

The factors involved and their interrelations are manifold. Any component of the forest may be concerned in the matter, as well as various influences from without. The study will draw upon all the resources of Entomology—Taxonomy, Morphology, Biology, Bionomics—and extend into other sciences, but it is primarily a study of the forest environment. If every opportunity is taken to prosecute the study of forest insect bionomics, the gradual accumulation of data eventually may enable many of these problems to be solved.

Variation in Habits. Variations in the factors of the environmental resistance are able to effect significant changes in the habits of the same insect species. A few interesting examples of varying habits have been met

with in recent investigations and many others are recorded here and there in the literature. Referring again to the spruce budworm, it was found that throughout the greater part of the eastern outbreaks the larvae hibernated in tiny silken cases on the twigs, and, appearing in the following spring at the time the buds of the balsam fir and white spruce were opening, they killed a large percentage of the buds and the new shoots before the latter had time to develop. This was a marked characteristic of the species everywhere, except in the island of Cape Breton. In that interesting country, the budworms emerged from hibernation after most of the buds had burst and the shoots had commenced to lengthen, with the result that the new shoots grew to nearly their normal length, the buds for the ensuing year developed normally at the tips, and the larvae merely stripped off the needles leaving the new twigs completely bare of foliage. Under these conditions the outbreak lasted apparently for about 15 years, instead of dying out in about 3 years, partly through starvation of the caterpillars, as had happened elsewhere.

In the cold, wet spring climate of that region, the cold and humid air conditions apparently retarded the development of the larvae without affecting so greatly the growth of the buds, so that a large proportion of the shoots were well started before the larvae appeared.

This outbreak disappeared finally under rather unusual conditions. Throughout our studies of the spruce budworm, parasites were found usually to play a minor role. In the Cape Breton outbreak, however, as in a few other localities, the parasites were rather more numerous than usual, and in 1927 the parasitism suddenly increased to more than 80% and the outbreak disappeared.

On a high plateau in northern British Columbia, some 3000 feet above the sea, a spruce budworm outbreak has been in progress for a considerable number of years in a forest composed of mountain balsam and Engelmann spruce. In that cold, wet climate, with frequent heavy rains throughout the summer, the budworm larvae develop in the first season of feeding to only the third or fourth stage without causing much defoliation, and go back to the twigs at the end of the season, spin a second hibernating cocoon, and pass the second winter therein. In the following spring they attack the foliage vigorously, causing a noticeable defoliation, and complete their course of development. The eggs are laid in the normal way and in the following year the larvae reach only the third or fourth stage as before.

There is in this case a two-year life cycle with noticeable defoliation appearing in the alternate years. The trees were not being killed by the budworm and the outbreak had apparently lasted for a considerable period of time.

The mountain balsam bark-beetle, *Dryocoetes confusus* Sw., is killing the timber in that forest rapidly and it exhibits a peculiar habit in cutting a second egg-tunnel as an extension of the first without the labour of excavating a new entrance hole, a habit which may also be related to the climate.

Throughout the province of Quebec and the Maritimes the spruce budworm injury occurred chiefly in pure stands of balsam and spruce. In mixed stands of hardwoods and balsam, the defoliation appeared mainly on the balsam tops which projected above the crown cover of hardwoods and, as a consequence, mixed stands were considered to be largely immune from severe budworm injury. They appeared to be so in Quebec and the Maritimes;

but when the budworm outbreak developed later in Central Ontario, the balsam fir beneath hardwoods in mixed stands was destroyed to a very high degree. It is therefore far from certain that mixed stands of hardwoods and conifers will be immune against budworm invasions.

In all the infestations which have been studied in Eastern Canada, the spruce budworm fed chiefly upon balsam fir and spruce and rarely fed at all on the foliage of jack pine. In the Lake States, however, there is a budworm which is considered to be the same species that feeds by preference on the needles of jack pine, and in Wyoming there is another which prefers the foliage of lodgepole pine. In one section of the Cape Breton island outbreak, the spruce budworm showed a preference for swamp spruce, which was being killed by the defoliation, although clumps of balsam fir in the same stand were but slightly injured.

The white-marked tussock is a common enemy of elms and other deciduous trees and is found occasionally feeding on balsam fir and larch. In 1928 and 1929 two outbreaks of this insect occurred in Nova Scotia on balsam fir in which the trees were heavily defoliated over an area of many acres in each case.

The food preferences of insects have been completely changed under pressure in experimental work, and there is some reason to assume that the same result may have been produced under natural conditions in the forest.

Host Selection. A very definite preference in the selection of their hosts is exhibited by many forest insects. In fact, many species breed normally in only one or at most a very few species of trees, and this preference is so strongly fixed that they can be forced to breed in other hosts only under pressure of very unusual circumstances. In the case of insect species which have only a few closely allied host trees it has sometimes been assumed that the individuals which had bred on one of the host species showed a distinct preference for the same species either for food or for the purpose of oviposition. This assumption often appears to be a logical one and has not been without the support of evidence in a number of cases. It cannot, however, be accepted yet as an established principle that has general application. The habit of each insect species requires to be studied in that regard on its merits, and there is some reason to suspect that certain species will exhibit considerable variation in the strength of their preference. The difficulties that may be met with in studying this subject are exemplified by the case of the mountain pine beetle (*Dendroctonus monticolae* Hopk.), in lodgepole pine and yellow pine in Western North America. Workers in California and Oregon have held the view that an outbreak of this species occurring in a lodgepole pine forest was not likely to spread into a neighbouring stand of yellow pine for the reason that the beetles, having bred in lodgepole pine, would almost certainly attack only that tree, at least until the lodgepole stands were destroyed. Naturally, there was evidence to support this view.

On the other hand, workers in British Columbia have long been convinced that in the forests of that province outbreaks of the mountain pine beetle have on numerous occasions developed in lodgepole forests and have spread down the slopes and into the yellow pine stands below. It is difficult to obtain conclusive proof under field conditions, but a study of the development and extension of these outbreaks in British Columbia, extending over a

period of many years, has convinced entomologists there that outbreaks of these beetles in lodgepole pine spread readily enough into yellow pine in the neighbourhood.

Experimental work with large cages has disclosed no evidence of any decided host selection. Infested lodgepole pine logs were enclosed in cages with an equal number of freshly cut lodgepole pine and yellow pine logs, and infested yellow pine logs were treated in the same manner. Several of these cages were employed in each of three successive years. In no instance was any preference shown. The beetles which emerged from yellow pine or from lodgepole pine went in approximately equal numbers into the yellow pine and into the lodgepole pine logs provided in the cages. It should be noted that this beetle breeds readily enough in cages of the type employed in the experiments, and there is, therefore, little reason to suppose that the caged conditions distracted them from the exercise of any normal preference.

It seems probable that the distinct differences in the course of outbreaks by this beetle, which have been noticed between those in southern British Columbia and those occurring in Oregon and California, may be paralleled by distinct differences in the matter of host selection.

Individual Selection of Trees. The evident selection exerted by the insects for individual trees or for trees in a definite condition of health is another matter of the greatest importance. It is well known that even at the height of a severe outbreak certain individual trees may be more or less completely exempt from injury. Many examples of this individual immunity have appeared in the course of investigations, and it has sometimes been suggested that immune races of trees might be propagated from these individuals with great advantage to forestry.

It is well known that most species of bark-beetles, even those which at times cause the most destructive outbreaks, select at normal times trees in a weakened or dying condition. *Dendroctonus piceaperda* Hopk., which breeds in the bark of spruce, normally selects for attack only the over-mature, weakened or dying trees, windfalls or logs. Under normal forest conditions, the species exerts a very definite selection for bark in a weakened or dying condition. When, however, the species has increased to enormous numbers, as often occurs in extensive windfalls or in great quantities of large slash left in cuttings, and a destructive outbreak develops, the beetles attack with apparent freedom all conditions of trees in the stand, excepting the small diameters of less than six inches. In one instance, it was found that 13% of the trees which were killed by the beetles had previously been growing as fast as any in the stand, 20% had been making the average diameter growth for the whole stand, and the remainder had been growing more slowly than the average.

It has frequently happened in Eastern Canada that an outbreak of this species killed approximately 50% of the larger spruce in an infested valley and then died away. Is it possible that the beetles are exerting any selection in their attack on the trees during the height of an outbreak, or that there is any reason why they attack that 50% and not the other?

Up to the present time the investigations of entomologists on this point have not been conclusive. It appears that resin production has little to do with the matter, all degrees of resin flow being exemplified in the trees which

are killed. Also the rate of growth does not appear to be related in white spruce with the production of resin.

Many peculiar vagaries in the matter of selection come to light in the study of trap-trees in bark beetle control. One incident will serve for illustration. An apparently healthy spruce, 10 inches in diameter was felled on June 15, 1932, and left lying on the ground. One week later only a few beetles of *Dendroctonus piceaperda* had entered the bark of the felled tree, but in the meantime a great swarm of beetles had attacked a healthy, 13 inch spruce standing nearby. Both trees had been retarded by sawfly defoliation for the previous four years. Cases such as this appear to suggest that under certain conditions individual trees may exert a definite attraction.

It is probable that the attraction which dying bark exerts on these beetles under normal conditions must be associated with chemical changes in the trees, presumably in the cell sap. Researches on the chemical changes which occur normally in trees from month to month throughout the season, and in trees which are slowly or rapidly declining in vigour should yield invaluable results.

There are many such problems in the forest which lead directly into the fields of biochemistry and plant physiology. Their solution will be achieved only through co-operation in research.

Reaction of Trees to Insect Attack. The reaction of the trees to the insect attack is a matter of the greatest interest and a problem that abounds with difficulties. In the case of species which normally attack trees that are unthrifty but to all appearances still alive, it is sometimes a matter of dispute whether the insects have actually killed the timber or whether they have merely selected trees which had already been weakened by other causes beyond the point of recovery. The attack of the balsam weevil (*Pissodes dubius* Rand.) on weakened balsam fir is a case in point. The broods of this species are invariably developed in trees which are unthrifty and which are making little or no diameter growth.

The broods develop to maturity only in trees which die rapidly shortly after the attack. If the infested tree does not die the larvae succumb when only partly mature. Unless the larvae are able, through the effect of their tunnels cut in the inner bark, to kill the weaker trees, it is evident that the females often make grievious mistakes in their selection. The beetles of this species excavate feeding punctures freely in the bark of healthy trees and, during a recent investigation in New Brunswick there appeared evidence that the effect of these feeding punctures, made over a period of years, may weaken trees to such a degree that eventually the broods can develop to maturity in the bark.

Insect Populations. The so-called population studies, in which an attempt is made to follow accurately the numbers of the species throughout the full course of its development, have achieved very interesting and practical results. In many cases, no doubt, the results have been much more interesting than practical, but the value of these studies is unquestioned. The very thoroughness with which the investigation must be planned and conducted through all its stages to completion ensures the best opportunity for obtaining the most essential data, and for discovering obscure habits and associations of the insects. The estimation of the original egg population, the larval

population in each instar, the pupal population and finally the adult emergence, conduct and oviposition, together with the mortality in each life stage and the causes of it, serve as a background on which a most complete investigation of the insect and its associations can be built.

The studies on bark-beetle populations in Europe made recently by Seitner, Golovyanko (*6*) and Iljinski (*7*) are excellent examples of a study of this kind directed to a practical end, in those cases, the determination of the number of trap trees required to absorb all the beetles that would be produced per unit area. The formulae that were developed no doubt represented the conditions met with in the outbreaks that were investigated, but the results of investigations of this sort cannot yet be applied generally to forest outbreaks. They must be made, in great part at least, on each individual infestation. Many such studies will be required on any insect species, representing many varied conditions, before much generalization can be made.

Forest Insect Biologies. There is a great need for more general knowledge of forest insect biologies. In the Cerambycidae and Buprestidae, not even the host tree is known for a number of the species, and in the case of these and many other forest insect groups there is an astonishing lack of information on the biologies of even some of the commoner species. In the general field, there is very little advance to be found in the literature since the time of Packard's 5th Report and Felt's Park and Woodland Insects. A great deal of information has been obtained, it is true, but the greater part of it has not yet been published. This is one field in which the young investigator can make sure and valuable progress.

The practical importance of studies in insect habits may be illustrated by reference to the generations and broods of bark-beetles. Until very recently, it had been assumed that many common species of these beetles, *Dendroctonus*, *Ips*, *Pityogenes*, and others, exhibited annually a series of overlapping generations. Through a series of careful investigations it has been shown that most of the bark-beetles in Canadian forests have, at most, only one generation each year, but that many species produce two distinct broods each season and in some cases even more. The same females cut one tunnel in early summer, lay the complement of eggs, feed for a short time and then emerge and cut a second tunnel elsewhere and deposit a second batch of eggs. The progeny from the first tunnel emerge early in the following summer; that from the second tunnel may emerge late in the following summer or may carry over in the bark until one year later, making a two-year life-history for the late season brood.

The same females of *Polygraphus rufipennis* Ky. have produced as many as three such broods in one season and lived over the winter to produce a fourth brood in the following season. Some species of northern origin, *Dendroctonus johnsoni* Sw. and *D. rufipennis* Ky., for example, have normally a two-year generation. It is possible that in the southern part of the continent some species may have more than one generation each year; but it has not been found to occur in the Canadian forest in either the East or in British Columbia. The fact that the parent beetles normally emerge shortly after the first tunnels are completed and enter other trees has an important significance in connection with control measures.

Overcrowding the brood sticks in cages has resulted in inciting a species which has normally only one brood per season to cut three separate tunnels and lay three batches of eggs. *Dendroctonus* species habitually overcrowd many of the trees they attack, but it is not yet known what effect this habit may have on the number of broods produced in the open.

It has also been learned that many species of bark-beetles belonging to the genera *Ips*, *Orthotomicus*, *Trypodendron*, and others, have the habit of leaving the brood trees during fine days in the late autumn and going into hibernation in the moss or under the litter beneath the tree. It seems an extraordinary habit for these beetles, but proves to be rather common in a number of genera. In the case of *Ips pini* Say and *Ips calligraphus* Germ., the majority of the young brood hibernate on the ground and a smaller portion cut food tunnels in the tops of dying trees. It appears that these few beetles in the tops have been able in the past to deceive us into a belief that burning the trees was sufficient for control and have sacrificed themselves for the benefit of the main population which was safely hidden under the litter.

The bionomics of forest insects is now receiving much greater attention than ever before, and a considerable amount of data on this subject has already been accumulated. Unfortunately, only a small proportion of it has appeared as yet in the literature. Ecological studies require this collection of data in large amount, and its subsequent collation and study occupy a great deal of time. Unless the results of the research together with the significant data are published, a large part of the benefit which should accrue is lost and much valuable time is wasted. Researches of this kind are perhaps as difficult as any in the field of Entomology and are usually of little value unless directed by well-trained and experienced investigators.

Twenty years ago the criticism was made, and with reason, that entomologists were paying too little attention to the bionomics of the insects they studied; today the criticism is being made by many economic entomologists that the schools have been paying too little attention to the fundamentals of entomology. It goes now without saying that every young entomologist should receive a sound training in the principles of bionomics, but it is surely quite as important that he have a thorough grounding in the classification, structure and general habits of the organisms which are to be the subject of his future investigations. When one considers the frequency with which undescribed species or unknown species appear in the course of our investigations, the difficulty in obtaining any reliable identification of collections in many important insect families, the paucity of our entomological literature on taxonomy—except in a few favoured groups—during the past half generation, and the not too hopeful prospect for young taxonomists to take over the load from those few stalwarts who are now bearing it for us so nobly, there is a tendency to hope for a revival in the study of the "three Rs" of Entomology, Taxonomy in association with Anatomy and Biology.

In concluding it may be said that the major forest problems include so many interrelations between various components of the forest complex that they can be dealt with successfully only by co-operative researches in several fields of science. The investigation of a forest insect outbreak may lead directly into research in silviculture, in mycology, in biochemistry, in plant physiology, and no one knows how much higher mathematics may be needed

to deal with the data that may be accumulated in its course. It is a satisfaction to know that entomologists are realizing the need for this co-operation with other scientific men, for, without any doubt, therein lies the greatest hope for the solution of our most difficult problems.

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PEACH CANKER INVESTIGATIONS[1]

I. Some Notes on Incidence, Contributing Factors and Control Measures

R. S. Willison[2]
Dominion Laboratory of Plant Pathology, St. Catharines, Ontario

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Throughout the peach-growing districts of Ontario, canker is recognized as one of the more serious diseases that infest the peach, linking up cultural and pruning practices with "die-back" of twigs and winter-injury and with the brown rot problem. Few, if any, peach orchards are free from canker; many of the older ones are seriously impaired by it, or its aftermath—heart-rot, and few of the younger ones escape its ravages.

During the years 1912-1917, McCubbin (*6*), then officer-in-charge of the St. Catharines Laboratory, carried on extensive investigations into the canker problem in the Niagara district. As the laboratory at that time had no orchard of its own, the work was done in several commercial orchards and observations were made, for the most part, on bearing trees.

The objects of the present investigations were in part to study the problem as it applied to the early as well as the later stages of an orchard, and to find if possible means for the control of canker by prevention. The scope of this paper is confined to the discussion of material obtained from intensive surveys conducted in the experimental orchard—the property of the laboratory—and to the formulation of such control measures as are suggested thereby. The former phase resolves itself mainly into the incidence of canker in different plots, the enumeration of points of origin of cankers, and a discussion of their relative importance. Isolations and inoculations, the causal organism or organisms, and other phases of the problem will be dealt with in future papers.

Review of the Literature

Although considerable work has been done on "die-back" of the peach and other stone fruits, there is comparatively little literature on canker in peaches. Caesar (*2*) reports that canker was not troublesome in Ontario until 1908. Rolfs (*7*, *8*), Walton and Babcock (*10*), McCubbin (*6*), Togashi (*9*) and others are agreed that the disease is fungal in nature and that the fungus, *Valsa leucostoma*, gains entrance by way of wounds. Rolfs claims that buds are also foci of infection. McCubbin lists the vulnerable points in the following order of importance: twigs, killed either by winter-injury, leaf-curl or "die-back"; pruning wounds; twigs killed by brown rot; crotches; dead buds; wounds other than pruning; frost cracks and blossoms blighted by the brown rot fungus. He also states that "Those districts, where the soil is hilly, and where there is deep sand with good drainage, are less affected than the low-lying, level lands where both air and soil drainage are poor. Even in the same orchard, a well-drained knoll *may be* much less subject to canker than the low, moister parts. The disease is noticeably worse also in

[1]Contribution from the Division of Botany, Experimental Farms Branch, Dominion Department of Agriculture, Ottawa, Ont.
[2]Plant Pathologist.

orchards situated in hollows, or closely sheltered by woods. In many cases there is such a marked difference in adjacent orchards that one cannot help concluding that *improper orchard practice has a great deal to do with the encouragement of the disease.*"[3] Caesar and Howitt (*3*) are "inclined to think that heavy pruning and heavy fertilizing, in combination with wet weather early in the growing season, may also have much effect in inducing the formation of cankers." Briton-Jones (*1*) considers that *Cytospora* (*Valsa*) is not able to cause "die-back" in strong, healthy trees and that infection is only possible after the trees have become sufficiently enfeebled, for example, by insufficient or excessive soil moisture or by starvation.

Description of Cankers

For present purposes, peach canker may be described as a more or less perennial lesion on the trunk or on the branches of the tree. In its early stages, it appears as a sunken, brownish area, usually disfigured by masses of exudant gum. The bark in the affected part is brownish when cut open, in contrast to the pale, yellowish green of healthy bark. Later the bark becomes shrivelled, blackish and separated from both the underlying wood and the surrounding bark. During the growing season callus formation decreases the size of the lesion, but usually, in the dormant season, the callus becomes infected either in part or in toto, so that old cankers are characterized by a series of rings caused by the death of successive overgrowths.

Description of the Orchard

The laboratory orchard, set out in the spring of 1928, was subdivided into various experimental plots arranged in such a way that various schedules of sprays, experiments in the length of the period of cultivation, and experiments in pruning more or less over-lapped. This arrangement (with the omission of the pruning experiments) along with the distribution of cankers of various origins throughout the orchard, is shown in Figure 1. It will be observed that the orchard consists of two hundred and forty trees of the Elberta variety, ten trees each of the varieties, South Haven, Yellow St. John, June Elberta, Rochester, J. H. Hale, Late Crawford, Vedette and Valiant, and five trees each of Mayflower and Greensborough.

In the surveys carried on during the latter part of the growing season of each year since the orchard was planted, drawings of individual trees were made and trunk diameters were measured at two to three inches above soil level. All important wounds and all cankers were located on the diagrams, and other items of interest such as the origin and development of cankers and the fate of wounds were noted. Most wounds and all cankers were measured at each survey and at various intervals between surveys. From the analysis of the data thus accumulated much valuable information has been obtained.

Centres of Origin of Cankers

As has already been pointed out, cankers originate at wounds or in dead areas, with a possible exception in the case of buds. In the orchard under observation, all cankers which have appeared until the fall of 1932 have been classified according to the sources from which they arose. The results of

[3] Italics are ours.

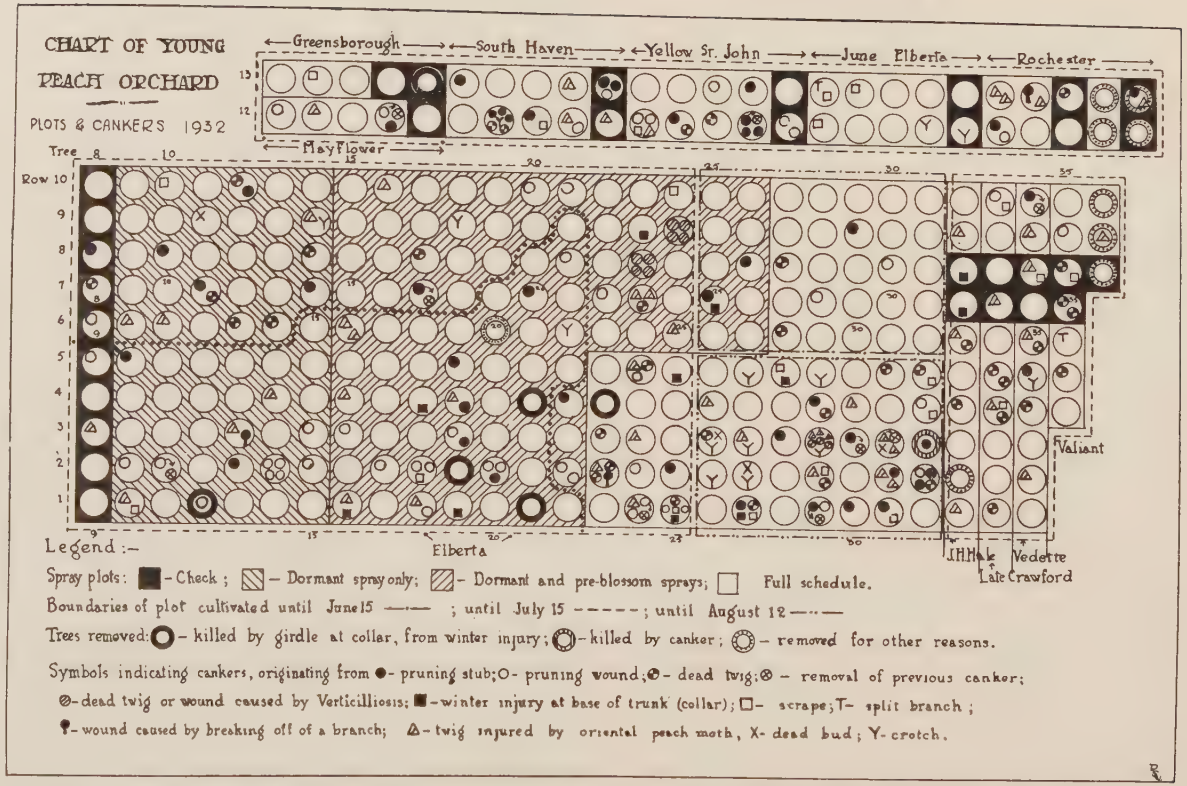


CHART OF YOUNG PEACH ORCHARD
PLOTS & CANKERS 1932
Greensborough
South Haven
Yellow St. John
June Elberta
Rochester
Mayflower
Tree
Row
Elberta
Valiant
Vedette
Late Crawford
Legend :-
Spray plots: - Check; - Dormant spray only; - Dormant and pre-blossom sprays; Full schedule.
Boundaries of plot cultivated until June 15 ——; until July 15 - - - - -; until August 12 —·—
Trees removed: - killed by girdle at collar, from winter injury; - killed by canker; - removed for other reasons.
Symbols indicating cankers, originating from ● - pruning stub; O - pruning wound; ⊘ - dead twig; ⊗ - removal of previous canker;
⊘ - dead twig or wound caused by Verticilliosis; ■ - winter injury at base of trunk (collar); □ - scrape; T - split branch;
- wound caused by breaking off of a branch; △ - twig injured by oriental peach moth, X - dead bud; Y - crotch.

Figure 1. Plan of experimental orchard, showing the varieties, the spray plots, the plots cultivated for different lengths of time, and the distribution of cankers of various origins.

this classification are given in Figure 2 which indicates the points of origin and the percentage of cankers developed from each, both for individual years and for the whole period.

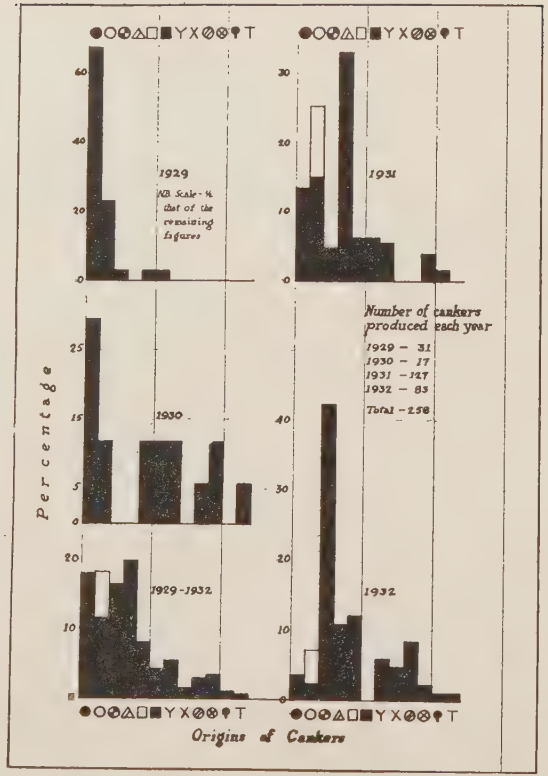
Considering first the total number of cankers, it will be seen that 72% of them originated in approximately equal proportions from four sources: twig injuries caused by Oriental Peach moth, pruning wounds, stubs and dead twigs. An additional 24.5% came from 5 sources, ranging from 8.4% to 3.1 % each, in the following order: implement scrapes, damaged crotches, winter injuries at the collar, pruning wounds caused by the removal of previous cankers, and injuries arising from *Verticillium* wilt. The remaining 3.5% developed from dead buds and from wounds caused by the breaking off or splitting of branches. These observations serve both to illustrate the relative importance of the various types of injury and to suggest, in part, means of preventing the disease.

It will also be seen, from the charts for individual years in Figure 2 that, as the trees become older, there is a tendency to shift the responsibility for cankers from pruning cuts to dead twigs, Oriental peach moth injuries, scrapes and crotches. Obviously details will vary from year to year with changes in the inter-action of a multitude of factors, but in all probability variations in the composite picture will not be significantly different from the trends already indicated.

As is well known, peach moth larvae eat their way down from the tip, inside succulent shoots, eventually to emerge through the side of the twig. Infested twigs naturally die, many of them slough off without further damage, but as shown above some of them do induce canker. The number of such cankers, of course, will fluctuate mainly with the prevalence of the moth.

The pruning cut is a necessary evil. Its importance in the canker problem largely depends on whether it is made as a stub in which part of the pruned twig or branch is left projecting, or as a pruning wound, by which is meant in this paper, a cut made flush with the surface of the parent branch. In these experiments, the pruning wounds greatly outnumbered the stubs, but in spite of that, the percentage of cankers which developed from the latter was approximately equal to that from pruning wounds, indicative of greater potential menace on the part of the stub. Incidentally, 36% of the pruning wound cankers appeared at wounds treated with either white paint, white lead, or tar, all of which are more or less toxic to exposed living tissues of the peach. Generally speaking, clean, unbruised, close pruning wounds heal rapidly, while stubs die to their base and thus provide an ideal site for canker development. For example, less than 1% of non-disinfected pruning wounds which were not healing well in the fall of 1930 produced cankers in 1931. Certainly if all pruning wounds of that year had been counted the percentage which developed into cankers would have been much less. On the other hand, 4.5% of all stubs recorded in 1930 became cankers in 1931.

Dead twigs and "die-back" twigs are certainly among the most important and fertile of starting points for cankers. Death may be due to any of a number of causes, but no attempt is made to separate them here, except to distinguish between twigs killed by brown-rot and those killed by other agencies. The former are treated in greater detail below.



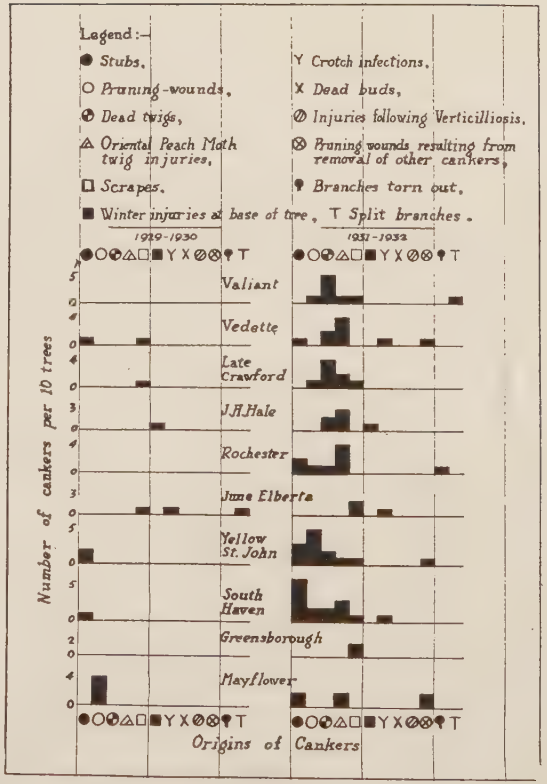


Figure 2 (left). Charts showing the percentage of cankers of various origins developed both in each year from 1929 to 1932 and during the complete period. The blank outlines in the pruning wound column represent cankers from disinfected wounds.

Figure 3 (right). Charts showing the occurrence of cankers of various origins in the different varieties.

Wounds incurred through the scraping of branches or trunks by harness, implements and so on, are fortunately numerically few in comparison to pruning wounds. Fortunately also, their number can be controlled to some extent by the exercise of proper care during the various necessary operations. It is desirable that such wounds be reduced to a minimum, because a fairly high percentage of them give rise to cankers. For example, out of 205 recorded between 1929 and 1931, 6.8% became cankerous.

Winter injuries at the base of the trunk, or collar, are important because from their location they can affect the whole tree if they become cankered and also because the tree may be girdled and killed in severe cases. The fact that 9.3% of the collar injuries of 1930 and 1931 subsequently became cankers is evidence of their vulnerability. This form of injury is not of regular occurrence although it was prevalent in 1930 when 22.4% of the trees in the orchard were affected and 7.5% of the damaged trees were killed.

Cankered and damaged crotches are also important by reason of their location. In practically every case where cankers formed the crotch was fundamentally weak, because the angle between branch and trunk was acute and because, on the upper side, there was no organic union between branch and trunk on account of the presence of dead compressed bark. Such crotches provide an ideal situation for the initiation of canker, and this condition is aggravated by a tendency for the tree to split at the crotch. The splitting is usually slight, but may be severe where growth is vigorous and the crop heavy.

The recurrence of cankers in 12% of the 75 cases of canker removal suggests the possibility that the canker-producing organism, at times, may be present in the wood considerably beyond the external limits of the lesion. Consequently it seems advisable when cutting out cankers to remove a considerable portion of the apparently healthy wood below the canker, especially where it has become well established.

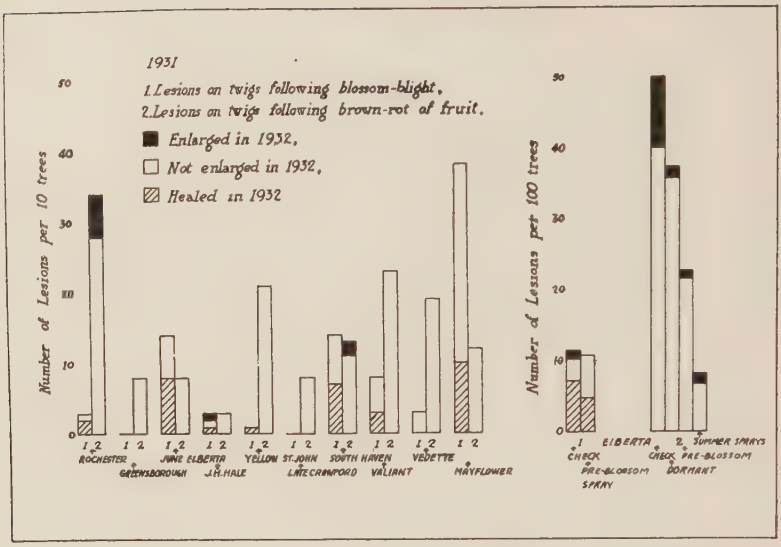
As a general rule, *Verticillium* wilt attacks young trees only and produces visible symptoms only in part of the tree, causing, apart from defoliation, two types of injury, dead twigs and dead sunken areas in the bark. Affected trees usually recover during the subsequent growing season, but sometimes the injuries become infected and give rise to cankers.

There is no doubt that infection may take place through buds and, although it has not yet been definitely established, there is some evidence that uninjured buds may be attacked. So far, dead buds have been of little importance in the direct initiation of canker, but indirectly their part may be more significant in so far as "die-back" is often the result of bud-infection.

Frequently in bearing trees, branches may be broken off or split either through being too heavily laden with fruit or through carelessness during harvest. Such injuries, of course, should be avoided as much as possible, since, besides causing more or less loss directly, they also serve as centres of infection.

Varietal Susceptibility

The numbers of cankers of various origins in different varieties are given in Figure 3. To date there are some indications of differences in varietal susceptibility but too much emphasis should not be placed on this phase of



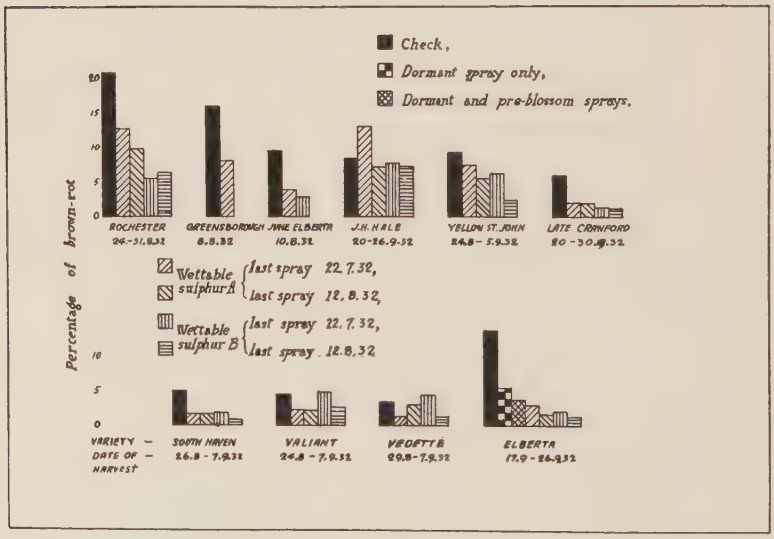


Figure 4 (upper). Charts showing the occurrence, in 1931, of lesions following both blossom blight and brown rot of fruit in the different varieties and, in the Elberta variety, in the various spray plots.

Figure 5 (lower). Charts showing the percentage, in 1932, of brown rot in check and spray plots of different varieties.

the problem at the present time. Suffice it to say that, from the data obtainable, South Haven and Yellow St. John rank among the more susceptible varieties, with Elberta, J. H. Hale, June Elberta and Greensborough among the moderately resistant.

Relation of Brown Rot to Canker

As the *Sclerotinia* sp. causing brown rot has been cited as causing canker (*4*, *5*), counts were made in 1931 of lesions on twigs and branches caused by infection both of blossoms and of fruit. As Figure 4 indicates, the majority of the former were healed over by the following summer and only a small percentage (2.2%) showed any increase in size. A larger number of twigs were injured by means of rotted fruit while 6.2% of the lesions spread during the winter. None, however, has resulted in the formation of definite cankers. Thus it would appear that *Sclerotinia*, in spite of its ability to attack wood and bark, is not in itself a serious factor in the canker problem. However, as both types of lesion are open to invasion by canker-producing organisms, *Sclerotinia* may assume considerable importance indirectly.

Experiments in Spraying

In order to study the effect of various spray programmes (Figure 1) the orchard was divided into plots receiving no sprays (checks), dormant spray only, dormant and pre-blossom sprays, and a full schedule, which in addition to the fore-mentioned included a shucks spray and two or three summer sprays, the last of which was applied six weeks before harvest. The materials used for the different applications, along with the rows on which they were applied are enumerated in Table 1.

Table 1.—*Summary of sprays applied to peach trees for the control of canker and brown rot.*

Application	Material	Rows
Dormant spray	Lime-sulphur 1-8	All rows
Pre-blossom spray	Lime-sulphur 1-50	1, 2, 3, 13.
	*Wettable sulphur A	4, 5, 6, 12.
	*Wettable sulphur B	7, 8, 9, 10.
Shucks and summer sprays	Wettable sulphur A	4, 5, 6, 7, 8, 13.
	Wettable sulphur B	1, 2, 3, 9, 10, 12.

*Wettable sulphur A is known under the trade name of Kolofog, and Wettable sulphur B under that of Koloform; both are put up by the Niagara Brand Spray Company.

A glance at Figure 8 reveals that canker is not amenable to control by spraying, since it happens that the plot receiving the largest number of sprays has the largest number of cankers. On the other hand, the use of fungicides materially decreases the incidence of brown rot. The graphs for the Elberta variety in Figures 4 and 5 show that both the number of twig lesions (1931) and the percentage of brown rot (1932) were reduced even by one or two applications and especially by the use of summer sprays. From the data given in Figure 5, it is evident that some measure of control was effected in most varieties, even in one so susceptible to brown rot as Rochester. Blossom

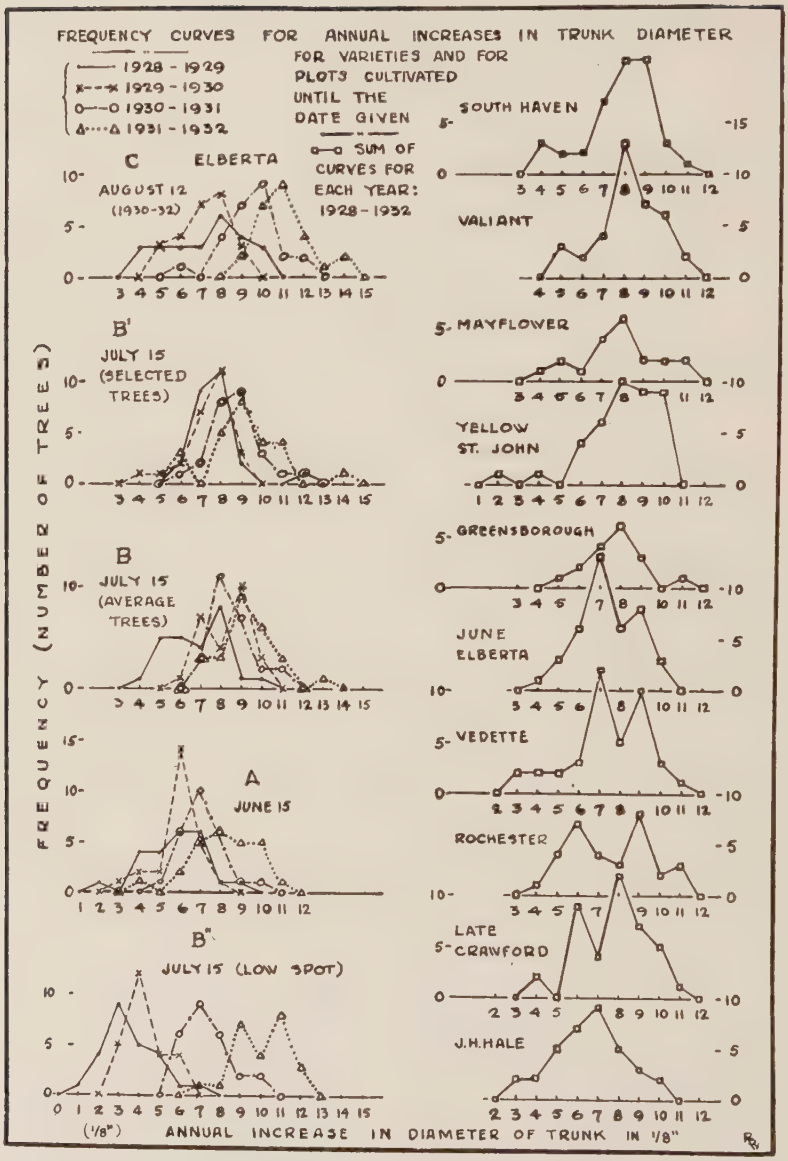


Figure 6. Frequency curves of annual increments in trunk diameter for each year in plots of the Elberta variety cultivated for different lengths of time. For the other varieties, the curves for individual years have been added together.

blight has not been severe in any year since the beginning of the experiment, so that it is impossible to make any statement here as to its control.

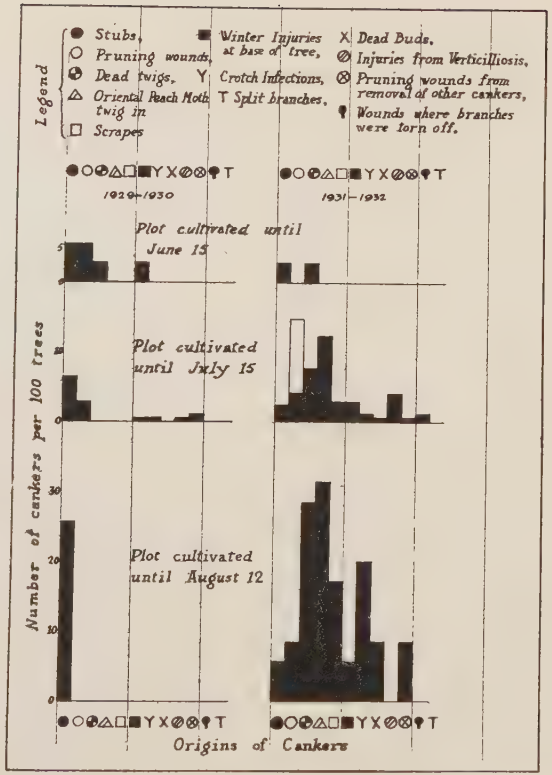
Obviously the control of brown rot of fruit is of major importance commercially, but it is interesting to find that both fruit rot and twig infection can be controlled by the same treatment. In fact because twig lesions generally follow very soon after infection of the fruit with brown rot, the former can be prevented only when the latter is reduced to a minimum. Fortunately, also, most twigs which develop Sclerotinia lesions are so placed that they can easily be removed without damage to the trees. They should be cut out, not only to lessen the possibility of canker but also to reduce the number of possible sources of brown-rot inoculum for the ensuing season.

Experiments in Cultivation

As it was considered probable that the degree of seasonal maturity attained by peach trees at the beginning of the dormant period might have an important bearing on the canker problem, it was deemed advisable to ascertain the effects of both prolonging and shortening the period of cultivation. Therefore the plot of Elbertas was sub-divided into three sections: A, cultivated until June 15; B, until July 15, and C until August 12. Cover crops were planted on the last day of cultivation. Plots A and B have been carried since 1928 but plot C was begun only in 1930.

The left-hand column of graphs in Figure 6 shows the range and distribution of annual increments in trunk diameter near the soil level of 25 trees in each of the various plots. It will be observed that the annual increase in plot A was from ¾ to 1 inch in the majority of cases, in comparison with 1 to 1⅛ inches in plot B and with 1¼ to 1⅜ inches in plot C during the last two years. (The means for each plot during 1930-1931, and 1931-1932 were: A, 0.92 inches; B, 1.09 inches and C, 1.27 inches). Previous to 1930, the prolonged cultivation was not operative in plot C, and the figures for the first two years were entirely comparable to those for plot B. Figures for plot B are given in three parts, because in addition to average trees, the plot contained a block of trees (B^{1} Figure 6) especially selected, when planted, for freedom from damage and for good root systems, and a low-lying, poorly-drained area in which the trees were retarded by adverse soil conditions (B^{11} Figure 6). The figures for 1928-29 seem to indicate that the selected trees became established more quickly and uniformly than trees in the rest of the orchard, but in subsequent years they had no apparent advantage over their fellows.

An interesting side light is thrown upon the influence of soil conditions on the peach by comparing the growth rates of the trees in the poorly-drained area before and after the installation of underdrainage. In this area, the location of which is shown enclosed by the dotted line in the lower left hand corner of Figure 1, the mean annual increase in trunk diameter was less than one-half inch during the years 1928-29 and 1929-30 as compared with 0.9 inches for the rest of the plot in the same periods, (see also B, B^{1} and B^{11} Figure 6). The orchard was underdrained in the fall of 1929. As a result of better drainage the mean annual increment during 1930-31 and 1931-32 for the trees in the "low spot" rose to 1.05 inches in comparison with 1.09 for the remainder. The recovery of the trees in the former is remarkable



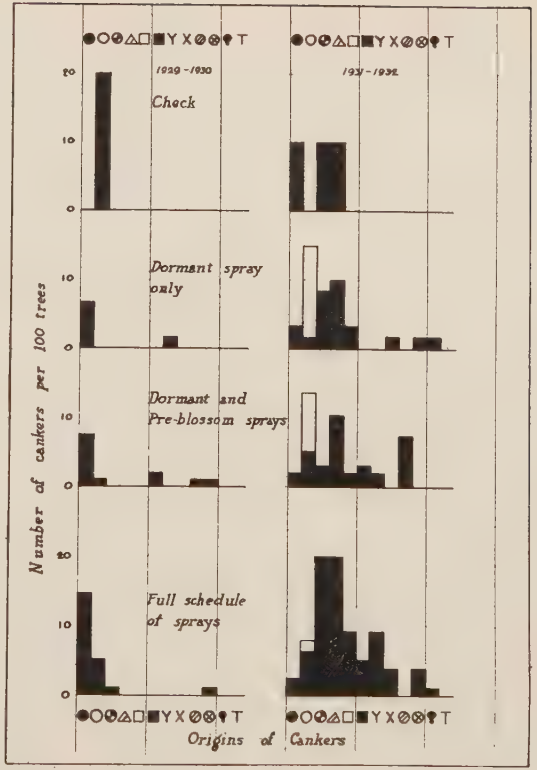


Figure 7 (left). Charts showing the occurrence of cankers of various origins in 1929 and 1930 and in 1931 and 1932 in the plots cultivated for different periods.

Figure 8 (right). Charts showing the occurrence of cankers in the various spray plots in 1929 and 1930 and in 1931 and 1932.

In both Figures 7 and 8 the blank outlines in the pruning wound column represent cankers from disinfected wounds.

especially in view of the fact that the response of the trees in the better drained parts of the plot B was comparatively slight.

The increase in the growth of the trunks with the greater length of the cultivation period is indicative of a corresponding increase in the time during which the trees were growing and therefore of a retardation of seasonal maturity. This was confirmed by observations on the foliage and buds. In August 1929 and 1930, the foliage in plot A took on a light yellowish green color, no new leaves were being produced and buds were well formed. At the same time the foliage of the rest of the orchard remained a deep green, besprinkled with the fresh lighter green of new leaves, while the buds were beginning to form. During the summers of 1931 and 1932, there was more rainfall than in the two previous years, so that the differences in foliage were not conspicuous, though, as before, new growth ceased and bud formation commenced earlier in the plots with the shorter periods of cultivation.

Some evidence of the adverse effects of prolonged cultivation was furnished by the relative prevalence of winter injury in plots A and B in the spring of 1930 when 22.4% of the trees in the whole orchard were damaged at the collar. Injury occurred, for the most part, on the west and south-west sides of the trees, though no side was entirely immune. In plot B, 25.3% of the trees were affected, but only 10% of those in plot A. Incidentally the damaged trees in the latter were on outside rows adjacent to B or to the varieties. Plot C at that time was non-existent. It may also be of interest that the majority of the trees killed by winter injury in 1930 were in the poorly-drained area.

A consideration of the incidence of cankers in these plots discloses a remarkable correlation with the condition of the trees at the beginning of the dormant period (Figure 7). The numbers of cankers appearing in the three plots during 1929 and 1930 were of the same order of magnitude, so that any differences can be attributed to chance. It so happened that plot A had then the largest number of cankers from "die-back" twigs and from winter injury, while the cankers in C all originated from stubs.

The situation became reversed, however, in 1931 and 1932 when the number of cankers per hundred trees rose from 5.8 in plot A, to 50.6 in plot B and to 134.4 in plot C. It would seem that the differences between these figures are too great to be merely coincidental, especially when the greatest increases occurred in those cankers whose origins may be associated with either succulence, seasonal maturity or vigour, namely: dead twigs, peach moth injuries, dead buds, crotches and winter injury at the collar. The larger number of cankers from implement injuries in C may be explained on the basis of the relative immaturity of callus as well as by the greater possibility of injury afforded by the larger trees. A similar explanation accounts for the increased number of cankers from stubs and pruning wounds. Crotch cankers affected 20% of the trees in C, but the damage to crotches in this plot was not confined to canker alone, for an additional 20% of the trees split either slightly or severely during the summer of 1932. On the other hand, splitting and cankering at the crotch was negligible in plot B and absent in plot A although weak crotches were fairly evenly distributed over all plots.

Experiments in Pruning

Pruning wounds and stubs evidently play such a considerable rôle in the initiation of cankers, that any investigations on this disease are not complete without experiments in pruning. As the relative importance of these types of pruning cuts has already been commented upon, attention here is directed mainly to the time of pruning and to the effects of disinfection on the resulting wounds. Varieties other than Elberta were pruned towards the end of the dormant season. Pruning was done in rows 1, 2, 8, 9, 10 (Figure 1) of the Elbertas during the dormant season, and in rows 3 to 7 at intervals during the summer. In rows 2 and 3 all pruning cuts were disinfected as follows: trees 9 to 14 with white lead made into a thin paste with boiled linseed oil; trees 12 to 20, with neutrum tar; trees 21 to 26, with corrosive sublimate 1:500, and trees 27 to 32 with 5% Agrisol.[4] In addition a few wounds were treated with a 10% solution of zinc chloride in 25% methyl alcohol.

The time of year at which pruning is conducted has a marked effect upon the rate of healing and therefore on the probability of canker formation. Generally speaking, pruning cuts made in the winter time do not heal so rapidly as those made in the late spring and early summer. If wounds are incurred during the dormant season there is necessarily a delay until spring before the healing processes begin. This means the occurrence of a certain amount of drying out and killing of the living tissue surrounding the wound. The resulting dead tissue is favourable to invasion by canker. The earlier in the dormant season the wound is made, the more the drying out and the longer the exposure to the possibility of infection. On the other hand, during the growing season, healing commences almost as soon as the wound is made, wound periderm is soon formed and callus is produced rapidly, especially during May and June. Later in the growing season, growth is slower. Consequently wounds made, for example in August, do not heal so quickly and the majority go into the dormant season only partly overgrown with callus. Observations showed that if trees were pruned in May or June, wounds were closed as soon as, and often sooner than, wounds made even as late as March. If pruning was done in December or January a larger percentage of the wounds were still open by the following October, by which time, most of the wounds made in March, April, May or June were healed. The following examples may be given to illustrate the relation of the time of pruning to canker formation. Of the pruning wounds of March, 1930, which were not healed by fall, 1.5% became cankered in the spring of 1931, in contrast to 0.2% of unhealed wounds made in May, June and July 1930. The fact that infection by canker-producing organisms is achieved more readily during the late fall, winter and early spring lends support to the view that wounds made during the dormant season are more subject to canker.

Pruning cuts involving the removal of leaders have proved to be more readily cankered than those by which laterals were cut off, although cankers have resulted from both types. This was especially true during the first year when most of the cankers made their appearance at cuts at the top of whips. As it is possible for a canker in this location to affect much of the top of the tree in later years, great care should be exercised in pruning a newly

[4] Agrisol is a trade name for an English creosote preparation.

planted orchard. It should be emphasized that although pruning cuts give rise to a certain percentage of cankers in an orchard of any age, they are responsible for the vast majority of cankers appearing in the first year or two.

Up to the present the disinfection of pruning wounds has not been entirely satisfactory. Zinc chloride, white paint, tar thinned with xylol, have been applied to various wounds with disastrous results, as may be seen in row 2 (Figure 1). White lead paste, without turpentine or excess oil, and unthinned tar were only slightly toxic. Mercuric chloride 1:500 and 5% Agrisol did not injure exposed tissue, but their effectiveness is probably short lived on account of leaching by rain. Even where disinfectants were non-toxic to the tree, disinfected wounds have not healed any more readily than untreated ones. In any case, when pruning wounds are properly made the percentage resulting in cankers is negligible, so that the benefits which might be derived from the disinfection of ordinary pruning cuts are likely to be small. However, it might be worth while to treat large wounds, which would normally require several years to heal over. Disinfectants which are toxic to the living tissues of the trees should not be used even on large wounds unless the vulnerable parts are first covered with some protective substance.

Preventive Measures

While it may not be possible to keep an orchard entirely free from canker, it should not be difficult to reduce the number of new cankers. A few control measures, suggested by a consideration of the factors already outlined in this paper, are briefly given as follows.

1. It has already been pointed out that the earlier in the dormant season that wounds are made, the greater is the probability of canker formation. The early part of the growing season is the best time to prune peaches, but as pruning at that time may not be practicable in commercial orchards, it should be deferred as late as possible in the spring, say until late March or April or even later. The making of close pruning wounds should also be emphasized as the stub is both undesirable and dangerous. Particular care in pruning is required during the first few years after setting out.

2. Remove all dead wood at pruning time. It is also worth while to make an inspection of the orchards late in June to take out any dead wood which was missed in pruning or which may have developed in the meantime.

3. Burn as soon as possible all dead wood and brush removed during pruning.

4. Avoid any cultural practices, such as cultivation beyond the first week in July, which will over-stimulate growth or send the trees into the dormant season in an immature condition. For the same reason, do not apply fertilizers after the early part of May. The short period of cultivation not only tends to reduce the occurrence of cankers, but is also a good horticultural practice. It is equally desirable to keep the trees in a thriving condition.

5. Avoid injury to the trees during cultivation, spraying and picking. Broken branches should be removed as soon as possible.

6. Remove and destroy during pruning all cankers on small branches and twigs. Cut them out at least a foot below the visible canker if possible.

7. Clean out in late spring cankers which cannot be removed and which are located at crucial points, and keep them free from gum.

8. Large wounds and cankers, after cleaning, may be disinfected with mercuric chloride 1:500 and covered with a protective such as white lead paste free from turpentine and with no excess of oil.

9. Spray during the summer months with a wettable sulphur, or dust with sulphur to control brown rot. Incidentally summer spraying also controls scab or ink-spot.

10. Remove rotted fruits from the trees in the fall and plough under or otherwise destroy them.

Summary

1. Cankers on the peach originate from wounds or dead areas such as: dead twigs, twigs injured by Oriental peach moths, stubs, pruning wounds, implement scrapes, damaged crotches, winter injuries at the collar, pruning wounds resulting from the removal of previous cankers, injuries following *Verticillium* wilt, dead buds, and broken or split branches. The relative importance of each of these points of origin is discussed.

2. Brown rot is of significance in the canker problem chiefly because it causes twig lesions which may serve as foci of infection for canker-producing organisms.

3. Cankers do not appear to be controlled by spraying.

4. Adequate spraying controls brown rot of fruit and twig lesions associated therewith.

5. Trees which are over stimulated by certain cultural practices and which are not seasonally mature at leaf fall are more subject to canker than thrifty trees which are properly matured.

6. There is some evidence of differences in varietal susceptibility to canker.

7. Pruning wounds made in the dormant season and stubs are cankered more frequently than pruning wounds made in the early growing season. Proper pruning practices are necessary in orchards of any age and especially so in newly planted ones.

8. Disinfection is valuable mainly in the case of large wounds.

9. A number of suggestions for prevention of canker have been enumerated.

Thanks are due to Dr. G. H. Berkeley for helpful suggestions and criticisms throughout the course of the investigations.

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CURRENT PUBLICATIONS

APPLE POLLINATION STUDIES IN THE ANNAPOLIS VALLEY, N.S. Under the Direction of W. H. Brittain. Bulletin No. 162, Dominion Department of Agriculture.

Apple Pollination Studies in the Annapolis Valley, Nova Scotia, represents the most comprehensive study of apple pollination so far attempted. In addition to a popular summary the bulletin consists of five main sections: (1) Introduction, discussing the general features of the apple industry in Nova Scotia having a particular bearing on the problem, together with a brief resume of factors other than pollination affecting fruit production; (2) Pollination and fruitfulness in apples in which the pollination problem in its various phases is outlined; (3) Experimental studies in apple pollination in which the exhaustive experiments undertaken in all phases of the problem are explained and the results concisely summarized; (4) Field studies in insect pollinators, in which the rôle of wild insect pollinators is explained and the problems connected with the utilization of hive bees are elucidated; (5) Studies in bee poisoning in which the results of experimental work undertaken to determine the cause and prevention of poisoning among bees due to spraying and dusting practice is fully set forth.

Though the work deals with experiments undertaken in Nova Scotia, an attempt has been made to attack the problem from a fundamental standpoint so that the results obtained are, to a large extent, applicable wherever apples are grown. It is shown that a pollination problem arises; (1) when self-unfruitful varieties, which includes practically all commercial sorts, are planted in solid blocks; (2) when cross-unfruitful varieties are planted together; and (3) when the population of pollination insects is inadequate to effect pollination. An important point that is clearly brought out in the studies is that apple varieties may be sharply divided into two groups, namely, good pollinizers and poor pollinizers. The first of these are suitable for pollination of others blossoming at the same time, the second are of inferior value or worthless for all other varieties. In the light of the foregoing the proper planting of orchards to secure adequate pollination is discussed and illustrated.

The work of wild and hive bees in pollinating orchards is fully discussed. The former were found to be more widely distributed than formerly disposed. The necessity of supplying hive bees to insure pollination in certain circumstances is explained and the proper method of distribution and placing is discussed. A full discussion of the factors resulting in bee poisoning is included, with methods of avoiding or minimizing such damage. The bulletin concludes with a list of literature cited and an excellent index.

While the bulletin is a technical one, a popular summary placed in the front sets forth in brief form the practical results of the investigation and this together with the charts, diagrams and figures with which it is profusely illustrated, will enable it to be used by the practical grower. Copies are available on application to the Publications Branch, Dominion Department of Agriculture, Ottawa.

AWNED HOODS IN BARLEY

RUNDALL M. LEWIS[1]
University of Toronto, Toronto, Ontario
[Received for publication January 14, 1933]

During a visit to China in 1929, Professor H. H. Love, of Cornell University, found at Kweiteh, Honan, a barley plant with unusual awns. Borne on the awns about halfway from the base to the tip was a structure resembling a hood, while the portion of the awn above the hood was variously flexed, giving the head a curly appearance. Later observation showed that this "curly" barley was distributed fairly widely throughout the plains region of Honan Province, occurring as an impurity in fields of normally awned barley. It had been grown experimentally at Kaifeng, Honan, where it bred true for the "curly" character.

Its intermediacy of form, and the circumstance that both awned and hooded barleys occur commonly where the intermediate form was found suggested that "curly" barley may have originated as a natural cross. On the other hand, any theory of the origin of this form must take account of its frequent occurrence (scatteringly present in about 5% of the barley fields near Kweiteh) and its genetic stability.

Biffen (*1*) used the terms "supernumerary floret" and "flowerless awn" in describing hooded and straight-awned types. "On crossing these hooded varieties with those bearing normal, i.e., flowerless awns, the hybrids in all cases are hooded, the supernumerary floret being borne either on the apex of the palea or on an awn from a half to two inches in length". In a later paper (*2*) he records some of his F_2 and F_3 results: "In the F_2 generation . . . there was considerable variation in the length of the awns carrying the supernumerary flowers, but no indications could be detected of segregation into individuals with sessile hoods, awned hoods, and true awns only". And further, out of 45 hooded F_2 progenies tested in F_3, "six individuals with hoods borne on awns of two or more inches in length from *H. Abyssinicum* × *trifurcatum* which were tested, all bred true to this character . . . The permanence of this feature suggestive of a blend of the parent characteristics was not expected, and no explanations can yet be offered to account for it".

G. von Ubisch (*3*) also discussed the genetics of awned and hooded barleys, assuming four factor pairs in interpreting her results:

> Factors A and K together give hoods which are reduced, but not wholly suppressed, in the presence of factor S.
>
> S is dominant over A and K singly; AAkkSS and aaKKSS are therefore awnless.
>
> Awns are of the constitutions AAkkss, aaKKss, and aakkss, and are long in the presence of factor I, short when I is absent.
>
> We have therefore hoods of the forms AAKKSS and AAKKss, but the former are, as we have said, much reduced, while our ordinary hoods are all AAKKss.

[1] Graduate Assistant.

An elaboration of the interaction of the factors thus proposed gives the following theoretical F_2 ratio:

Reduced hoods	81
Ordinary hoods	27
Long awn	9
Short awn	28
Awnless	111
Total	256

It is apparent that in this scheme one individual out of 81 (or more or less if the proportions are modified by linkage) will be homozygous, and will have the formula AAKKIISS. This, then, would be the true-breeding awn-hooded form for which Biffen has no explanation to offer. It is true that Biffen's true-breeding progenies were apparently derived from six individuals out of 45; but Biffen does not state the relation of these six individuals to his total population, and it seems possible that they all came from a single homozygous F_2 plant.

These results provide a possible basis for the hybrid origin of the "curly" barley of Honan. The necessary assumptions in this case are the natural crossing of awned and hooded barley and the persistence of a homozygous segregate. There is no indication that either artificial hybridization or artificial selection has played any part in the establishment and distribution of "curly" barley as suggested in this paper.

Summary

A barley occurring under field conditions in China is found to resemble a true-breeding progeny of hybrid origin reported by Biffen in 1907.

This barley is intermediate between awned and hooded.

The relations between awns and hoods proposed by von Ubisch in 1923 suggest a possible explanation of this resemblance, and of the origin of the form found in China.

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   I. Z. ind. Abst. u. Vererb. *17:* 120-152. 1916.
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A PRELIMINARY NOTE ON AN UNREPORTED ROOTROT OF OATS[1]

G. B. Sanford[2]
Dominion Laboratory of Plant Pathology, University of Alberta, Edmonton, Canada
[Received for publication September 12, 1933]

A serious rootrot of oats, which has been under my observation, developed in a wide area in the Edmonton district, during the crop season of 1933. Although the distribution, symptoms and etiology of the disease are not yet fully understood, sufficient information is available now to briefly describe its general appearance for those who might be able to recognize it elsewhere.

Approximately 50 fields of oats near Edmonton were examined and evidence of this rootrot was found in each field, and in many cases the loss was very marked. Apparently this rootrot may appear in local or in general areas, or on single plants, at any time during the crop season. In the field, the symptoms are most marked on plants from four to eight weeks old, and especially so before the crown root system appears.

The lower leaves of affected plants droop, turn light brown to reddish and slowly wither. Such plants assume an upright condition, with rather narrow leaves and reduced foliage, and are stunted and chlorotic, according to the severity of the attack. The general above-ground appearance of these plants in the field and in the greenhouse is indicated in Figure 1, A. In spite of an advanced blighted condition, affected plants tend to recover when the crown roots develop, but the emergence of the panicle from the sheath may be delayed and its size and number of spikelets definitely reduced. Diseased plants commonly have one tiller, in contrast to healthy plants, which may produce more. Another symptom, both in field and greenhouse, is the tendency of the lower part of the culms between the nodes, and also the nodes of affected plants, to develop a reddish to mauve pigment. With the latter exception, the general above-ground symptoms are somewhat similar to the effects produced by "browning" rootrot of cereals, described by Vanterpool and Ledingham (*1*).

The effect on the part of the plant below ground is also fairly definite. The primary roots are greatly reduced from normal development. These, and the sub-crown internode, commonly become straw-colored, but rarely darker until later. The crown itself appears to remain bright colored and normal for some time. The roots from the crown area may be attacked also. On the primary roots, the sub-crown internode, and sometimes above the crown later, may be seen minute dark sclerotia-like bodies, barely visible to the naked eye. These are illustrated in Figure 1, B. When magnified, on natural or stained tissue, these bodies are seen to be firmly attached by hyphae to the host. Cultured, these minute masses rather consistently yield a fungus, the aerial hyphae of which is cream to white colored, and which, during early growth, stains potato dextrose agar yellow. Although the pathogenicity of this fungus has not yet been established, its constant association with the disease would suggest that it causes the symptoms described.

[1] A contribution from the Division of Botany, Experimental Farms Branch, Department of Agriculture, Ottawa, Canada, co-operating with the University of Alberta.
[2] Plant Pathologist in Charge.

FIGURE 1.

A. Left: stunted plants grown in greenhouse in soil from unhealthy field. Note upright condition, dead lower leaves, narrow foliage, and coloring of lower portion of culms.

B. Dark fungal masses typical of those on the sub-crown internodes and primary roots of stunted plants.

Dr. G. R. Bisby, University of Manitoba, who kindly examined a culture, reported tentatively as, "I would say that the sporulating fungus is a *Gliocladium*, probably *G. roseum*". Field symptoms were reproduced on oats grown in infested soil in the greenhouse, while the same soil sterilized, and also other soil, apparently healthy, unsterilized, yielded normal plants. A more complete account of this malady will be available shortly.

REFERENCE

1. Vanterpool, T. C., and G. A. Ledingham. Studies on "browning" rootrot of cereals. Can. Jour. Res. *2:* 171-194. 1930.

CURRENT PUBLICATIONS

STERILIZATION OF NARCISSUS BULBS BY IMMERSION IN SILVER NITRATE-POTASSIUM CYANIDE SOLUTION IN VACUO. W. Newton, R. J. Hastings and J. E. Bosher. Canadian Journal of Research *9*: 31-36. July 1933.

Through the use of a dye solution, evidence was obtained that a liquid disinfectant may be forced into the narcissus bulb parts invaded by nematodes and fly larvae by immersion *in vacuo*. An investigation of the lethal properties of solutions against nematodes and their influence upon bulb growth led to the selection of a silver nitrate solution as a promising disinfectant, but owing to instability of silver nitrate in the presence of chlorides and other substances in tap water and in dirt clinging to bulbs, its use had no commercial possibilities. However when silver salt was combined with potassium cyanide in the ratio of 1 to 3 by weight, an effective solution of satisfactory stability was obtained. A solution of silver nitrate 0.05% and potassium cyanide 0.15% by weight, forced into narcissus bulbs by an evacuation process, effectively destroyed bulb nematodes and bulb fly larvae without significant injury to bulb growth under greenhouse conditions. Field tests with bulbs treated in silver nitrate-potassium cyanide solutions resulted in the reduction of infection from 26.8 to 1%, a 96% control, and no evidence of injury in the foliage or bloom was detected.

RESUME DES ARTICLES PUBLIES EN ANGLAIS DANS CE NUMERO

L'avenir de la science agricole. Sir A. Daniel Hall, Directeur, John Innis Horticultural Institute, Londres, Angleterre.

Le développement considérable de la spécialisation en science agricole est discuté par l'auteur qui fait ressortir la difficulté qu'il y a à maintenir en contact avec le côté pratique de l'agriculture les savants occupés à des travaux de recherches hautement spécialisés. L'auteur recommande que chaque technicien s'occupant de recherche ait constamment à résoudre quelque problème d'ordre pratique en plus de son principal travail de recherche. Le problème de la santé des animaux devrait être envisagé beaucoup plus au point de vue de la prévention des maladies au moyen d'une nutrition convenable et de soins généraux qu'au point de vue de la guérison des maladies. Le temps est venu où notre connaissance des principes de la génétique que nous ont appris la sélection des plantes et l'élevage des petits animaux devrait être employée à la création de races spécialisées de nos principaux animaux domestiques. En raison de son coût, pareil travail devrait être entrepris sur une base coopérative par plusieurs centaines de fermiers sous la direction d'un expert. Des recherches d'ordre économique s'imposent en agriculture. L'auteur pense que les améliorations dans la pratique agricole que peuvent apporter les recherches agronomiques ne sont pas suffisantes pour contrebalancer le sévère handicap économique auquel est sujet le fermier isolé du type paysan. L'auteur préconise l'organisation des cultivateurs en vue de la production et de la vente organisées.

Influence des insectes sur de developpement des forets. J. M. Swaine, Service fédéral d'entomologie, Ottawa, Ont.

L'auteur fait ressortir le changement dans la composition des forêts qui s'est produit depuis la colonisation du Canada. Depuis cette période les insectes ont détruit environ trois fois autant d'arbres que le feu. L'auteur discute les déprédations de certaines espèces et les relations entre les insectes et le milieu forestier. Il est désirable que des recherches de nature coopérative soient entreprises entre les différentes sciences qu'intéresse la question.

Recherches sur le chancre du pecher. R. S. Willison, Laboratoire fédéral de pathologie végétale, St. Catharines, Ont.

Le chancre du pêcher a son origine dans des parties de l'arbre blessées ou mortes telles que rameaux ou bourgeons morts, blessures de taille, blessures résultant d'attaques par des insectes ou des cryptogammes. L'importance relative de ces différents points d'origine est discutée par l'auteur. La pourriture brune est importante dans le problème du chancre parce qu'elle produit des lésions dans les rameaux qui servent ensuite de foyer d'infection aux organismes producteurs du chancre. Le chancre ne semble pas être contrôlé par des pulvérisations mais celles-ci peuvent contrôler la pourriture brune du fruit et prévenir les lésions des rameaux qui en résultent. Les arbres trop stimulés par certaines pratiques culturales et qui ne sont pas convenablement aoûtés sont plus sensibles que les autres aux attaques de chancre. Les diverses variétés semblent avoir des susceptibilités différentes. Les blessures de taille faites pendant le saison de repos semblent se chancrer plus facilement que celles faites au début de la période de croissance. La désinfection des blessures présente de l'intérêt surtout pour les blessures les plus grandes.

Orge a capuchon barbu. Rundall M. Lewis, Université de Toronto, Toronto, Ont.

L'auteur discute la ressemblance entre une orge sauvage trouvée en Chine et une orge d'origine hybride signalée par Biffen en 1907.

NOTE PRELIMINAIRE SUR UNE POURRITURE DES RACINES DE L'AVOINE. G. B. Sanford, Laboratoire fédéral de pathologie Végétale, Université de l'Alberta, Edmonton, Alberta.

L'auteur décrit une pourriture des racines de l'avoine jusqu'ici non signalée et qui semble associée à la présence d'un champignon, probablement *Gliocladium roseum*.

NOUVELLES

Les membres de la C.S.T.A. ont appris aves plaisir la nomination de M. P. Nolasque April (Laval '15) au poste de Directeur de la nouvelle Ecole d'Agriculture de Ste-Martine, P.Q. Bonne chance et bon succès au nouveau Directeur.

J. R. Pelletier (Laval '27), autrefois assistant-regisseur à la Station Expérimentale de Farnham, a été transferré à la Station Expérimentale de Ste-Anne de la Pocatière comme assistant-regisseur.

NOTES AND NEWS

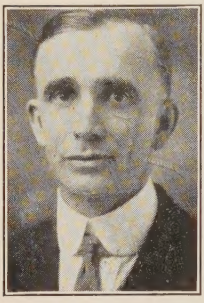
BEGINNING VOLUME XIV

The current issue of *Scientific Agriculture* is the first number in Volume XIV. There will be no change in editorial policy, but we will strive to improve constantly. It is an exceedingly difficult task to satisfy all subscribers continually, as the limits of space prevent the inclusion of enough articles each month to appeal to the varied interests of all. We will continue to attempt to include at least one item a month which should have a fairly wide appeal. In this issue, everyone should read Sir Daniel Hall's analysis of the future of agricultural reaserch. It was spoken of at Regina as one of the best addresses ever delivered to the Society. Sir Daniel Hall was head of the British delegation to the World's Grain Exhibition and Conference and is recognized as one of the outstanding agricultural leaders of the world. Another article which is of wider interest than usual is Dr. J. M. Swaine's address on forest insect activities. Dr. Swaine, Associate Domininon Entomologist, was honoured by an invitation from the Entomological Society of America to give the annual address at the Atlantic City meeting last December. While very few technical agriculturists are closely connected with forestry, most of us have a love for the forests and are interested in their conservation. Some day we may find forestry much more closely connected with agriculture than at present. Dr. Swaine's paper is an excellent summary of the insect situation and well worth reading as a matter of national importance.

NOTES AND NEWS

J. K. KING, DEPUTY MINISTER FOR NEW BRUNSWICK

The appointment of Mr. J. K. King as Deputy Minister of Agriculture for the Province of New Brunswick has recently been announced. Mr. King, who is a native of Sussex, New Brunswick, graduated from Macdonald College in 1913. For three years he was District Depresentative for Pontiac County, P.Q. From 1916 to 1927 he was District Sheep and Swine Promotor for New Brunswick, from which position he resigned to become Manager of the Maritime Marketing Board. In 1928 he came to Montreal as Secretary of the Canadian Live Stock Co-operative, and since 1932 has been associated with the Co-operative Federee of Quebec.



Mr. King enters upon his new duties with a sound knowledge of the agricultural problems of New Brunswick, and a speaking acquaintance with hundreds of farmers throughout the province. Having had the benefit of experience in the federal department and in commercial life he has a good understanding of the necessity of co-ordinating the extension activities of provincial services with those of other departments and organizations. In a rpovince where the agricultural staff is not large and at a time when curtailment is taking place in various services, both federal and provincial, unified action is necessary. Mr. King's experience and tact will be a great asset to the New Brunswick Department in carrying on existing services and in widening its activities as conditions permit.

DOMINION LIVE STOCK BRANCH REORGANIZATION

As announced in the August issue of *Scientific Agriculture* the separate Divisions which existed in the Dominion Live Stock Branch have disappeared to be followed by two sections known as Services—Live Stock Field Services and Live Stock Market Services.

Mr. R. S. Hamer, formerly Chief of the Cattle Division, becomes Assistant Live Stock Commissioner and Chief of Field Services. Mr. A. McMillan becomes Associate Chief in charge of Sheep and Wool Services. Mr. A. W. Peterson is Assistant Chief in charge of Cattle and Swine, and Mr. F. G. Semple is Assistant to Chief. Mr. C. S. Wood remains Chief Inspector of the Record of Performance for Cattle and Mr. W. L. Graham remains Supervisor of Cow-Testing. The field services in each province have been placed under the direction of the following men:

T. B. Stewart, British Columbia.	S. Boily, Quebec.
John Norquay, Alberta.	J. H. King, New Brunswick.
F. C. Whiting, Saskatchewan.	J. A. Steele, Nova Scotia.
Dr. A. S. Morrison, Manitoba.	S. D. Irvine, Prince Edward Island.

Ontario will be administered from headquarters at Ottawa.

Mr. W. J. McCallum, formerly Chief of the Stockyards Service becomes Chief of the Market Services. An Assistant to Chief with experience in horses remains to be appointed. Mr. P. E. Light retains charge of the Markets Intelligence Service as Markets Analyst and Editor. Mr. W. A. Brown remains as Chief of Poultry Services, with S. C. Barry, Assistant Chief and E. D. Bonyman, Chief Market Poultry Inspector. Mr. R. W. Zavitz as Chief Poultry Inspector retains charge of R.O.P. for Poultry and of Hatchery Approval.

REORGANIZATION AT MANITOBA AGRICULTURAL COLLEGE

Dr. A. Savage Appointed Dean

Reorganization of the staff of the University of Manitoba has recently taken place. The necessity for economy, arising out of the unfortunate financial situation which prevails, has made it necessary to eliminate positions wherever possible. The elimination of the purely administrative office of Dean has brought about the retirement of Dean W. C. McKillican.

The new Dean, Dr. Alfred Savage, was born in Montreal and graduated from Macdonald College in 1911. From 1911 to 1914 he attended Cornell University where he received the degree of D.V.M. During the war he served in the Canadian Army Veterinary Corp, returning to Macdonald College to hold the position of Veterinarian from 1919-21. Since 1921 he has held the position of Professor of Animal Pathology in the University of Manitoba. He took post graduate work at the Royal Veterinary College at Edinburgh during 1927-28 and is a member of the Royal College of Veterinary Surgeons.

Dean Savage is widely known as one of the outstanding animal pathologists in Canada. He has many research papers to his credit and is a member of several American and Canadian scientific societies. In addition to holding the respect of his colleagues in veterinary circles, he is regarded by technicians generally as a thorough scientist, and by farmers as a sound agriculturist. The fact that he has been chosen to head the Faculty of Agriculture at such a critical time in the history of the University places a heavy responsibility on his shoulders. Those who know him realize that Dean Savage will give vigorous leadership in the present crisis. He will retain his teaching position in addition to handling the administrative duties of Dean of the Faculty of Agriculture and Home Economics. The following will make up the staff under his direction for the year 1933-34.

Agricultural Staff, University of Manitoba

A. Savage, Professor of Bacteriology and Animal Pathology.
F. W. Broderick, Professor of Horticulture and Forestry.
M. C. Herner, Professor of Poultry Husbandry.
G. W. Wood, Professor of Animal Husbandry.
R. W. Brown, Professor of Dairy Husbandry.
G. P. McRostie, Professor of Agronomy.
A. V. Mitchener, Professor of Entomology.
J. McC. Brown, Associate Professor of Animal Husbandry.
J. H. Ellis, Associate Professor of Agronomy.
N. James, Assistant Professor of Bacteriology.
M. C. Jamieson, Lecturer in Bacteriology.

Home Economics Staff, University of Manitoba

Mrs. L. C. Duncan, Director of Home Economics.
Miss M. C. Hiltz, Assistant Professor of Nutrition.
Mrs. J. South, Lecturer in Household Art.
Miss C. L. Groff, Lecturer in Clothing and Textiles.
Miss E. G. McFadden, Lecturer in Clothing and Textiles.
Miss M. C. Moxon, Lecturer in Education.
Miss F. E. M. McLauchlin, Lecturer in Nutrition.
Miss L. Panton, Instructor in Institutional Management.

In addition to the staff listed, the following members of other Faculties will be concerned with Agricultural and Home Economics students:

M. A. Parker, Professor of Chemistry.
W. F. Geddes, Professor of Chemistry.
W. A. Anderson, Lecturer in Physics.
V. W. Jackson, Professor of Zoology.
G. R. Bisby, Professor of Botany.
C. R. Hopper, Associate Professor of English.
H. C. Grant, Associate Professor of Agricultural Economics.
G. L. Shanks, Associate Professor of Civil Engineering.
R. W. Youmans, Physical Instructor.

NEWS ITEMS

N. A. MacRae (Queen's '28), Tobacco Division, Central Experimental Farm, Ottawa, has recently been made a Fellow of the American Association for the Advancement of Science.

H. Groh (Toronto, '08), Botanist, Central Experimental Farm, Ottawa, was married on September 16th to Miss Mildred M. Krupp of Amyot, Ontario.

F. H. Peto (Manitoba, '28), Division of Biology and Agriculture, National Research Laboratories, Ottawa, was married on September 9th to Miss Ruth Beverley Robertson of Edmonton, Alberta.

K. W. Neatby (Saskatchewan '24), has received a National Research Fellowship and is studying under Sir R. H. Biffen at the School of Agriculture, Cambridge, England.

E. G. Booth (Saskatchewan '21), is now Chief of the Applications and New Business Division, Federal Land Bank of St. Paul. His home address is 1767 Bayard Ave., St. Paul, Minn.

J. F. Booth (Saskatchewan '19), Commissioner of the Agricultural Economics Branch, Dominion Department of Agriculture, Ottawa, has been invited to spend three years in India as economic advisor on agriculture to the Imperial Government. The request for Dr. Booth's services was formally transmitted through the British Government to the Canadian Government. The Dominion Department of Agriculture felt that his services could not be spared, and Dr. Booth will remain in charge of his department. This is fortunate, as work for this Branch of the Dominion Department of Agriculture is increasing rapidly, especially along the line of co-operative effort with other branches and with provincial departments and institutions. During the last two years Dr. Booth has represented agricultural economics on several interdepartmental committees including committees of the Inperial Economic Conference in 1932, and it is most desirable that his services should continue to be available to Canadian agriculture.

W. B. Gornall (Nova Scotia '09), Assistant to Dominion Fruit Commissioner, Ottawa, has been transferred from the Department of Agriculture to the position of Fruit Commissioner to Great Britain under the Department of Trade and Commerce. He will take up his new position in London shortly, where he will do investigational work in the interests of the Canadian fruit industry. For the past three years he has been chief of the markets division in the Fruit Branch. He had practical experience in fruit farming in the Annapolis Valley of Nova Scotia previous to entering the government service. Mr. Gornall was born in England and served with the Imperial forces during the Great War. His many friends in Canada, while regretting his departure to England, congratulate him on his appointment to this important post.